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Weldon Spring Site Remedial Action Project

Remedial Design/Remedial Action Work Plan for the Quarry Residual Operable Unit

Revision A - DRAFT

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Prepared by

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1. INTRODUCTION

The Quarry Residuals Operable Unit (QROU) is the second of two operable units established for the quarry area of the Weldon Spring site. The Quarry Bulk Waste Operable Unit, which was the first operable unit, addressed the excavation and relocation of the radiologically and chemically contaminated materials within the quarry to temporary storage at the chemical plant area and ultimate placement in the on-site disposal cell. Bulk waste excavation was carried out in conjunction with a removal action to extract, treat, and discharge contaminated water from the quarry sump. The QROU addresses (1) any residual soil contamination remaining in the quarry proper after completion of bulk waste removal, (2) surface water and sediment contamination in the Femme Osage Slough and nearby creeks, and (3) groundwater contamination north of the slough.

1.1 Purpose and Scope

This plan is intended to fulfill the requirements for both the remedial design and the remedial action work plans for the implementation of the *Record of Decision for Remedial Action for the Quarry Residuals Operable Unit at the Weldon Spring Site* (Ref. 1). The U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE) signed the *Record of Decision* on September 30, 1998.

This Work Plan is the primary document used in defining the design and implementation of the selected remedial action for the QROU. This plan has been prepared in accordance with the Federal Facilities Agreement between the DOE and the EPA (Ref. 2) and the Comprehensive Environmental Response, Compensation, and Liability Act of 1986 (CERCLA).

This Work Plan provides the following:

- The design strategy for the selected remedy and other activities (i.e. quarry restoration).
- The implementation approach for these activities.
- The major deliverables that will convey the design and construction activities of the selected remedy.
- The overall schedule under which the remedial design and remedial action activities will be conducted.
- General cost estimates for the activities.

1.2 Background

The Record of Decision presents the selected remedial action for the QROU. The action was selected following the requirements of CERCLA. The selected action stipulates long-term monitoring of groundwater to ensure continued protection of human health and the environment. Institutional controls will also be implemented to prevent groundwater usage inconsistent with recreational uses, or uses that would adversely affect contaminant migration. Field studies will be performed to collect data to verify the existing fate and transport model for the quarry area and to support ongoing evaluations regarding the benefits of groundwater remediation. Information presented in the Remedial Investigation/Feasibility Study Work Plan (Ref. 3), the Remedial Investigation (Ref. 4), the Baseline Risk Assessment (Ref. 5), the Feasibility Study (Ref. 6), and the Proposed Plan (Ref. 7) prepared for the operable unit was used to develop the selected action.

The objective of the Feasibility Study (Ref. 6) was to identify an alternative that provided a feasible option for removing or reducing the amount of uranium present in the groundwater north of the slough. Other components of the operable unit were determined to be acceptable based on the results of the risk assessment (Ref. 5). The feasibility of reducing uranium levels in groundwater north of the slough was evaluated because of the potential for impacts to the groundwater south of the slough, namely the St. Charles County well field.

During the evaluation process, the extraction of groundwater from the areas of greatest uranium contamination was identified as the most cost effective option to reduce the mass of uranium present in the groundwater north of the slough. The performance of this option was projected on the basis of available site-specific data. Calculations estimated that the extraction system may reduce the mass of uranium within the alluvial aquifer by 8% to 10% over a 2-year operating period. Uncertainties are still associated with the implementation of this option. The percentage that could be removed constitutes only a relatively small reduction in uranium in groundwater north of the slough and does not provide a measurable increase in protectiveness. The selected remedy includes a field study involving an interceptor trench to collect additional data to verify the projected performance of this option and to evaluate the benefit of groundwater extraction for uranium removal. Additional field studies to further validate the contaminant fate and transport model will also be performed.

1.3 Components of the Quarry Project

The quarry project can be divided into two tasks: (1) implementation of the *Record of Decision* for the QROU and (2) final reclamation of the quarry area. Since the implementation of both projects is necessary to attain final closure of the quarry area and has impact on the final configuration of the quarry, the design and construction activities of all activities necessary to complete these projects have been integrated into this *Plan*.

1.3.1 Quarry Residuals Operable Unit

Components of the operable unit include soil in the quarry proper, surface water and sediments in the slough and nearby creeks, and contaminated groundwater north of the slough. Each of these components was investigated during the remedial investigation phase to determine the nature and extent of contamination resulting from quarry disposal activities or the migration of contaminants in groundwater and surface water.

1.3.1.1 Soil in the Quarry Proper

At the quarry proper, soil was sampled from the rims and slopes, and sediment was sampled from wall and floor fractures and from the ramp and floor of the quarry sump. Two areas, the northeast slope and ditch area near the transfer station, which exhibit levels significantly higher than background were not completely characterized because of poor access during soil investigations. Radiological and chemical results from these samples indicate that under a recreational scenario, potential exposures including the northeast slope and ditch area are below to within the acceptable risk range of 10^{-6} to 10^{-4} (Ref. 5).

These two areas will be further characterized to delineate the extent of radiological contamination (see Section 5). Samples collected from these two areas during the remedial investigation phase indicate the presence of radiological contamination, however, additional samples need to be collected to sufficiently define the magnitude and extent of contamination.

The determination on remediation of the soils along the northeast slope area will be based on the results of a risk assessment to be performed using the additional data collected from the characterization effort. If response action is necessary, the cleanup criteria for radionuclides presented in the *Record of Decision for Remedial Action at the Chemical Plant Area* (Ref. 8) will be applied. The extent of any soil removal at the northeast slope will be protective of human health and the environment, but will not include the relocation of State Route 94.

It has been determined that characterization of the ditch area will be performed in support of the quarry restoration project. If levels are greater than the cleanup criteria discussed above, those soils will be removed. Incorporation of the characterization data from the ditch area will not be included in the risk assessment outlined in the *Record of Decision* (Ref. 1).

1.3.1.2 Surface Water and Sediment in the Slough and Nearby Creeks

Surface water and sediment from the upper and lower reaches of the Femme Osage Slough, the Little Femme Osage Creek, and downstream portions of the Femme Osage Creek have been characterized for radiological and chemical contamination. Fish from the slough were collected and analyzed to investigate any potential impacts from site contaminants.

Radiological and chemical results from the surface water and sediment samples indicate that under a recreational scenario the potential risk estimated for the slough and creeks is within the acceptable risk range of 10⁻⁶ to 10⁻⁴ (Ref. 5). The current levels of contamination in surface water and sediments from the slough and the Little Femme Osage Creek do not appear to have affected ecological resources at these habitats and do not pose a future risk to biota at the site. The results from the risk assessment indicate that no action is warranted for the surface water and sediments in the slough and nearby creeks.

1.3.1.3 Groundwater North of the Slough

Groundwater from the well field (located south of the slough) is used for residential purposes and monitoring data indicate that uranium levels in this area are similar to background levels. The contaminated quarry groundwater is not accessible to either current or future recreational users. For informational purposes, risk estimates for groundwater were calculated for a hypothetical residential user. At some locations north of the slough, the potential estimated risk is greater than the acceptable risk range of 10^{-6} to 10^{-4} (Ref. 5).

Because source removal was accomplished under a previous action, no new migration of contaminants to the groundwater system should occur. However, because of the presence of significant levels of uranium in groundwater north of the slough (2,200 pCi/l), it was considered prudent to continue an evaluation of the effectiveness and benefit of reducing the levels of uranium in the groundwater in the quarry area through field studies. The available hydrological and geochemical information, as well as water quality data, supports the conclusion that site contaminants will not measurably affect the aquifer of the Missouri River alluvium south of the slough. However, given the reliance on natural systems to preclude potentially significant impacts to this aquifer, alternatives addressing groundwater remediation were evaluated in the Feasibility Study (Ref. 6).

Long-term groundwater monitoring with institutional controls on groundwater usage in the area of impact was presented as the selected action in the *Record of Decision* (Ref. 1). The selected action addresses groundwater contamination by monitoring to provide data for verifying that conditions in the quarry area and the well field remain protective of human health and the environment. This determination will be made based on the collection of groundwater data from strategically selected monitoring wells, both inside and outside the area of groundwater impact. This data will also document any continued effects of natural processes on contaminant concentrations within the area.

This action will be designed to provide for long-term monitoring of groundwater, including the groundwater in the Missouri River alluvium. Existing wells, with the possible addition of several new monitoring wells, will be utilized in this network. If long-term monitoring identifies a trend or change in monitoring wells south of the slough resulting in

increased levels of uranium approaching a threshold level of 30 pCi/l, the potential for significant impacts to the well field and the alluvial aquifer will be reevaluated.

Chemical- and action-specific applicable or relevant and appropriate requirements (ARARs) for the selected action are discussed in the *Record of Decision* (Ref. 1). Chemical ARARs set concentration limits or ranges in various environmental media for specific hazardous substances, pollutants, or contaminants of concern. Missouri water quality standards in groundwater for nitrobenzene (176 mg/l), 2,4-dinitrotoluene (DNT) (0.11 mg/l), and 1,3-dinitrobenzne (DNB) (1.0 mg/l) are chemical-specific ARARs for quarry groundwater. Currently, only a few locations exceed the Missouri water quality standards for groundwater. It is projected that these ARARs are likely to be met within a reasonable period of time and that long-term monitoring of the groundwater will establish compliance with these limits.

The standard for uranium in groundwater outlined in 40 CFR 192.02 was considered as a potential ARAR for this action during development of the *Feasibility Study* (Ref. 6) and *Proposed Plan* (Ref. 7). The groundwater north of the slough is impacted, however, it is not considered to be a usable groundwater source. Conversely, the Missouri River alluvium south of the slough is currently not impacted and is presently being used as a potable water source. Because groundwater north of the slough is not a useable source, 40 CFR 192.02 is not considered an ARAR for that groundwater. However, 40 CFR 192.02 would likely be an ARAR for any remedial action considered for the useable groundwater source south of the slough in the unlikely event of contaminant migration from north of the slough. While 40 CFR 192.02 currently appears to be the only groundwater standard that would be considered as a potential ARAR for any future remediation, other standards in place at the time of any future action would also be considered in the ARAR analysis.

Institutional controls will be necessary to prevent uses inconsistent with recreational use, or uses that would adversely affect contaminant migration. Coordination with the Missouri Department of Natural Resources and the Missouri Department of Conservation (affected landowners), will be performed to establish a written agreement, such as a license agreement, memorandum of understanding, or deed attachment, outlining and agreeing to the terms of the institutional controls. Terms may include limiting access to groundwater north of the slough for the following uses: irrigation, consumption, etc. The terms of the agreement will be evaluated periodically based on the results of the long-term monitoring program. Changes or deletions to the terms would be made, as appropriate, based on the results of this program.

During bulk waste removal activities, the U.S. Department of Energy (DOE) developed the *Well Field Contingency Plan* (Ref. 9) to ensure the continued availability of a safe and reliable public water supply for St. Charles County. Specific activities, which were undertaken as part of this plan, were:

- Continued water quality monitoring to detect trends or abrupt changes in contaminant levels near the well field.
- Contaminant transport calculations and numerical modeling of the Weldon Spring Quarry and St. Charles County well field hydrogeologic system to enhance the understanding of processes controlling groundwater flow and contaminant migration.
- Definitions of action levels and response actions.
- Preparation of a plan for hydrogeological characterization to support development of a replacement well field.
- Development of design criteria for design and construction of a replacement well field

The objectives of the Well Field Contingency Plan (Ref. 9) will be integrated into the long-term monitoring program for this operable unit. The contingencies outlined in the Contingency Plan will be reevaluated based on current data and understandings and may be updated and will be summarized in a revision of the Well Field Contingency Plan.

Field studies are planned given the presence of significant levels of contamination in quarry groundwater north of the slough, which is in close proximity to the St. Charles County well field, and the reliance on natural systems to limit potential exposure. The following studies will be conducted to support the selected action described in the *Record of Decision* (Ref. 1):

- Studies to support the evaluation presented in the *Feasibility Study* regarding the need for and effectiveness of groundwater remediation, which includes an interceptor trench.
- Field sampling to further characterize the conditions controlling the fate and transport of uranium in the shallow aquifer.

1.3.2 Quarry Reclamation

Components of the reclamation of the quarry area include restoration of the quarry proper, demolition of the quarry water treatment plant, removal of the interceptor trench system (field study), and dismantlement of facilities utilized during bulk waste removal activities. The reclamation of the quarry area is planned as a two-phase project that includes the restoration of the quarry proper and the dismantlement of the quarry interceptor trench system, including the quarry water treatment plant. Because the water treatment plant will need to be available to treat water

from the interceptor trench, dismantlement of the treatment plant can not be implemented until after the activities related to the field studies have been completed. It is expected that restoration of the quarry proper itself will be completed before demolition of the treatment plant can be implemented. Grading of the site during quarry proper restoration will be performed to an intermediate site plan. Final site grading will be performed after demolition of the quarry water treatment plant.

The quarry proper restoration design plan includes backfilling the quarry with soil to:

- Reduce fall hazards.
- Eliminate ponding of surface water.
- Force groundwater flow around the inner quarry.
- Reduce the infiltration of precipitation through the backfill.
- Prevent the mobilization of residual contamination in fractures to the surface through erosion and/or freeze/thaw action,

Dismantlement of the facilities utilized during bulk waste removal activities would also be performed during this time. This includes removal of:

- Decontamination facility.
- Transfer station.
- Fuel station.
- Associated piping.
- Ancillary structures.
- Haul road structures.

Final reclamation of the quarry area will be performed at the completion of the interceptor trench field study. Reclamation will include:

- Demolition of the quarry water treatment plant and associated basins.
- Dismantlement of the interceptor trench.
- Grading of the treatment plant and interceptor trench areas to conditions that are as close, as possible, to natural contours.

1.4 Document Organization

The remaining sections of the document are:

- Section 2 <u>LONG TERM MONITORING</u> provides a summary of the groundwater monitoring program stipulated in the selected remedy. Also, a discussion of the institutional controls that will be performed in support of the long-term monitoring will be presented.
 - Section 3 <u>INSTITUTIONAL CONTROLS</u> provides a summary of the institutional control measures that will be employed on the restriction of groundwater usage in the area of impact. Also, a summary of an evaluation that will be made to determine the need for institutional controls on groundwater after completion on this action will also be presented.
 - Section 4 <u>FIELD TESTING</u> provides a summary of the interceptor trench and hydrogeological studies that will be performed to evaluate the benefits of uranium removal in the area north of the slough. Sampling methods and performance evaluations will be summarized in this section.
- Section 5 QUARRY PROPER SOIL provides a summary of the soil characterization activities to be performed in the quarry proper. Sampling methods will also be included in this section. A discussion of potential soil removal approaches is also provided.
- Section 6 <u>QUARRY RECLAMATION</u> provides a summary of the restoration of the quarry area after completion of the remedial activities being performed under this operable unit. A summary of the environmental assessments performed in support of the selected remedy and quarry reclamation activities is also included.
- Section 7 <u>CONSTRUCTION ACTIVITIES</u> provides a summary and construction specifications of the activities which will be undertaken to implement the selected remedy and quarry reclamation.
- Section 8 PROJECT SCHEDULE provides an overall schedule for the design and implementation of the different activities discusses in this plan.

- Section 9 <u>SUMMARY OF PROJECT COSTS</u> provides a summary of the costs for design and construction for the selected remedy, as well as the additional activities.
- Section 10 <u>QUALITY ASSURANCE PROGRAM PLAN</u> provides a brief abstract of the project quality assurance program plan.
- Section 11 <u>CONTINGENCY PLAN</u> provides a brief abstract of the project emergency preparedness plan.
- Section 12 <u>POST-ROD DOCUMENTS</u> provides a summary of the primary and secondary documents that will be prepared for the remedial design and remedial action phases of the QROU.
- Section 13 <u>REFERENCES</u> provides a summary of the reference documents used in preparation of this plan.

2. LONG-TERM MONITORING

This section outlines the long-term monitoring program to be implemented for the Quarry Residuals Operable Unit (QROU). The selected remedy for the QROU provides for continued protectiveness to human health and the environment by addressing the contaminated groundwater north of the slough. The selected remedy provides the following key components:

- Monitoring of groundwater long-term to verify that groundwater quality at the quarry area and the St. Charles County well field remains protective of human health and the environment;
- Implementation of institutional controls to prevent groundwater uses inconsistent with recreational use or uses that would adversely affect contaminant migration (see Section 3), and
- Collection of field data related to the effectiveness of uranium recovery in quarry groundwater to validate predictive models relating to groundwater remediation that were presented in the *Feasibility Study* (Ref. 6) (see Section 4).

The monitoring portion of the Well Field Contingency Plan (Ref. 9) has been integrated into the long-term monitoring program for this operable unit. In the event an alternate source of drinking water is required, engineering design and construction will proceed based on the design criteria established in a future revision of the Well Field Contingency Plan. The Contingency Plan will also outline the preliminary planning and preparation that will be necessary to implement the construction of a partial or full replacement well field, if the Contingency Plan needs to be implemented.

In the future, if the Missouri River alluvium is no longer used for potable water due to relocation of the production wells or closure of the water treatment plant, it will be recommended to cease long-term monitoring activities. The threat to human health and the environment will no longer exist; therefore, this action would be concluded.

This section outlines the following components of the groundwater monitoring program:

- Monitoring approach.
- Monitoring locations.
- Parameters.
- Sampling frequencies.
- Sampling and analytical methods.
- Criteria for continuation or conclusion of the monitoring activity.
- Monitoring well design.

- Specifications for the installation or retrofit of monitoring wells.
- Actions to be performed as a result of monitoring.
- Data reporting.

The Federal Facilities Agreement (Ref. 2) requires the preparation of an operations and maintenance plan for each operable unit continuing actions, such as monitoring or treatment. This section has been prepared to fulfill the requirements of this plan; therefore, a separate document will not be prepared for this operable unit.

2.1 Monitoring Approach

Long-term monitoring for the QROU consists of two programs that are designed to:

- 1. Monitor uranium levels south of the slough (St. Charles County well field) to ensure they remain below the threshold level of 30 pCi/l.
- 2. Monitor contaminant levels within the area of groundwater impact north of the slough until they are below the threshold levels of 300 pCi/l for uranium and 0.11 μ g/l for 2.4-dinitrotoluene (DNT).

As stated in the *Record of Decision* (Ref. 1), the potential for significant impacts to the well field and the alluvial aquifer will be reevaluated if long-term monitoring identifies a trend or change resulting in increased levels of uranium south of the slough approaching a threshold level of 30 pCi/l. The threshold level of 30 pCi/l is sufficiently above the established natural variation of uranium in the alluvial aquifer to be a useful indicator of currently unanticipated migration from the quarry.

Although uranium levels in groundwater north of the slough are relatively high, levels in monitoring wells south of the slough and at the production wells in the St. Charles County well field have been within background ranges (Figure 2-1). Monitoring to ensure uranium levels in groundwater north of the slough are below present levels would be prudent to ensure that potential impacts to the well field are negligible. The recent maximum uranium level in groundwater north of the slough is 3,380 pCi/l. Establishing a metric at 10% of this maximum would result in a threshold level of 300 pCi/l for comparison of the distribution of uranium in the plume north of the slough. This value falls within a 10⁻⁴ risk, which is the upper bound of the Environmental Protection Agency's acceptable range. Monitoring of groundwater south of the slough would continue as discussed above until these levels are met north of the slough.

Long-term monitoring of groundwater will evaluate the decreases in uranium and nitroaromatic compounds north of the slough, which are expected to continue as a result of bulk waste removal activities completed in 1995. Six locations (1008, 1013, 1014, 1015, 1016, 1027,

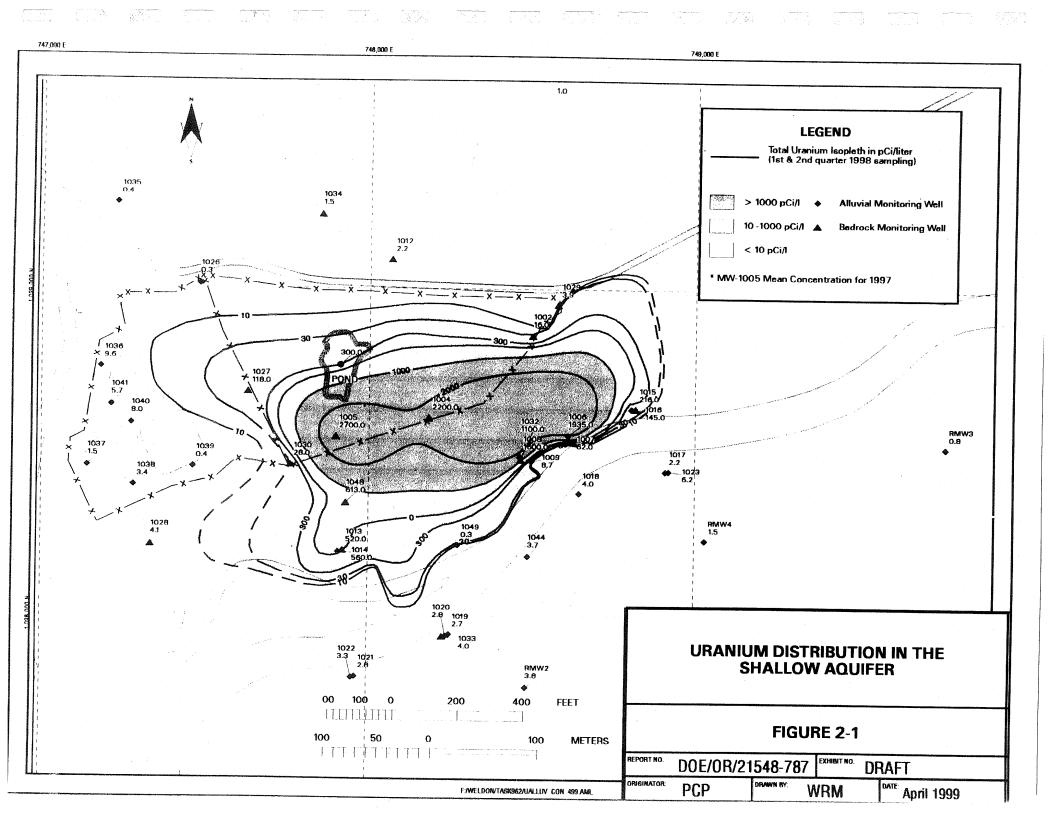


Table 2-1 Annual Averages for Total Uranium (pCi/l) and Nitroaromatic Compounds (μ g/l) in Groundwater North of the Slough for Calendar Year 1998

LOCATION	URANIUM	1,3,5-TNB	1,3-DNB	2,4,6-TNT	2,4-DNT	2,6-DNT
1002	16.0	19.0	0.13	5.27	0.06	5.00
1004	2200	0.21	ND	1.06	0.10	0.32
1006	1935	29.34	ND	1.44	0.09	0.52
1007	62.0	ND	ND	ND	ND	ND
1008	1600	ND	ND	ND	ND	
1009	8.7	ND	ND	ND	ND	ND
1013	520	ND	ND	ND		ND
1014	562	ND	ND	ND	ND	ND
1015	216	2.65	ND	1.15	ND	ND .
1016	145	0.12	ND		ND	0.16
1027	118	ND ND	ND	0.08	ND	0.03
1030	28	ND		1.38	0.46	1.13
1031	160	ND	ND	ND	ND	ND
1032	1100	ND	ND	ND	ND	ND
1046	13.2		ND	ND	ND	ND
1047		NS	NS	NS	NS	NS
1048	3.7.	NS	NS	NS	NS .	NS
	613	NS	NS	NS	NS	NS
1049	< 0.7	NS	NS	NS	NS	NS

Note: ND designates "not detected" NS designates " not sampled"

and 1032) (Figure 2-1) have shown greater than 20% reduction and three locations (1004, 1006, and 1032) have shown greater than 10% reduction in uranium concentrations from 1997 to 1998 (Ref. 10). A 40% reduction in TNT and an 18% reduction in DNT concentrations were also observed from 1996 to 1997 (Ref. 11). The 1998 annual averages for uranium and nitroaromatic compounds in each well north of the slough are summarized in Table 2-1.

The reduction in the contaminant levels in groundwater north of the slough will result in a decrease in the already low potential for migration south of the slough. Contaminant levels north of the slough have been projected to decrease with time as a result of:

- Adsorption of uranium onto the fine-grained aquifer materials.
- Precipitation of dissolved uranium in groundwater in the area of the slough where decaying organic matter maintains a reducing condition.
- Adsorption of nitroaromatic compounds onto organic matter in the materials north of the slough.
- Degradation due to reducing conditions and biological activity.

A notable decrease of uranium (from 2,200 pCi/l to 10 pCi/l) occurs over a short distance (100 ft to 300 ft) north of the slough, which indicates that processes other than dilution and dispersion are reducing the amount of dissolved uranium in groundwater. These processes include sorption onto the aquifer matrix and organics and precipitation of dissolved uranium from the groundwater. Contaminant removal from groundwater via precipitation of solid phases typically results from changes in geochemical conditions in the aquifer system. In the shallow aquifer north of the slough, uranium activity decreases abruptly near the northern margin of the slough in response to a sudden decrease in the oxidation potential, which is coincident with a reduction of dissolved uranium in the groundwater. The sharp decrease in uranium levels indicates that sorption, which typically generates more diffuse boundaries, is not the only process attenuating the uranium in groundwater.

The long-term monitoring network will be used to monitor changes in the geochemical nature of the shallow aquifer. If changes in uranium or nitroaromatic compound levels are observed, the geochemical data can be evaluated for possible mechanisms for changes in contaminant levels. Also, changes in the natural system can be determined prior to the possible occurrence of contaminant migration.

2.1.1 Groundwater Monitoring North of the Slough

The criteria for monitoring groundwater north of the slough will be the collection of samples for the performance of statistical analyses that can determine the following:

- The trend of the contaminant data at each location (increasing, unchanged, or decreasing) and the rate of change.
- The 90th percentile of the distribution of uranium concentrations from all locations north of the slough are below 300 pCi/l for a monitoring year.
- The 90th percentile of the distribution of 2,4-DNT concentrations from all locations north of the slough are below the 0.11 μ g/l for a monitoring year.

2.1.2 Groundwater Monitoring South of the Slough

The criteria for monitoring groundwater south of the slough will be the collection of samples for performance of statistical analyses that can determine the following:

• The trend of the contaminant data at each location (increasing, unchanged, or decreasing) and the rate of change.

• The 90th percentile of the distribution of uranium concentrations from all locations north of the slough are below 300 pCi/l for a monitoring year.

2.1.3 Geochemical Monitoring of the Shallow Aquifer System

The criteria for monitoring groundwater geochemistry from both north and south of the slough will be to determine if the geochemistry of the shallow aquifer has remained within natural variation at each location over the year monitoring period. Trends at each location may be evaluated to determine the occurrence of changes, if necessary.

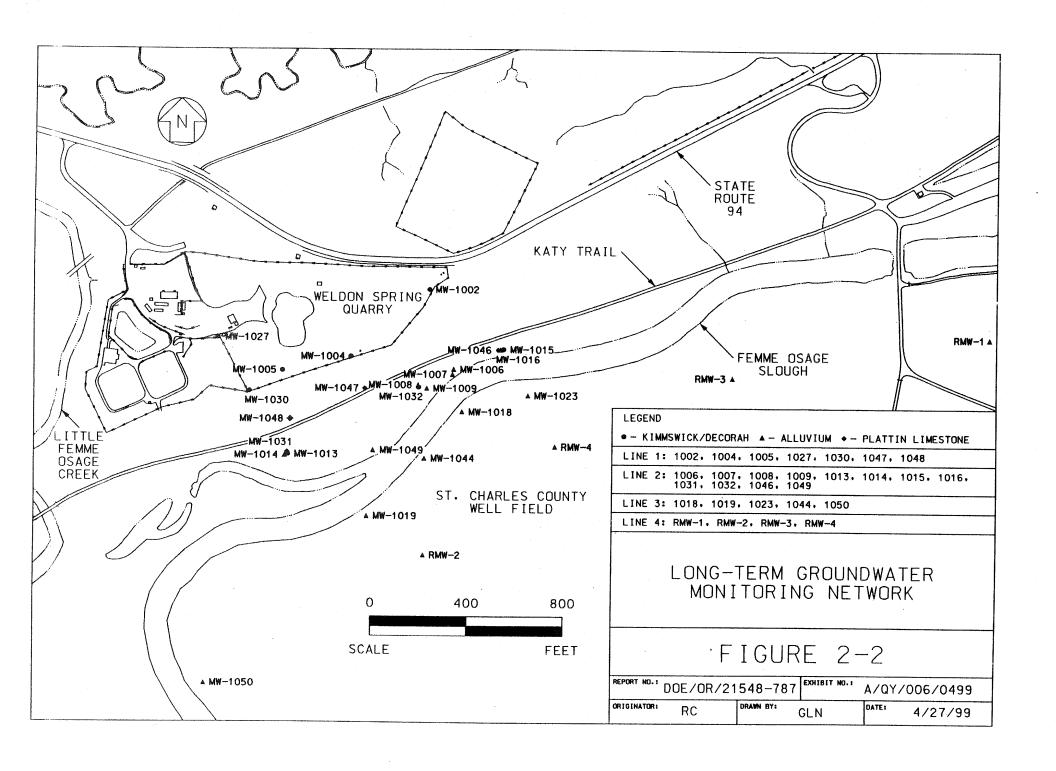
2.2 Monitoring Locations

A network of wells to be monitored as part of this action will be designed to provide for long-term monitoring of groundwater (Figure 2-2). Existing wells, with the addition of one new monitoring well west of the area of impact, will be utilized in this network. Presently, the environmental monitoring well network consists of all active wells in the vicinity of the quarry, which includes:

- Nineteen wells that monitor groundwater in the bedrock (Kimmswick Limestone, Decorah Group, or Plattin Limestone)
- Thirty wells that monitor groundwater in the alluvium both north and south of the slough
- Eight production wells used by St. Charles County to obtain potable water.

The groundwater monitoring strategy for the quarry consists of a stepped approach, which will continue to be implemented for this *Plan*. The long-term wells will be monitored to provide data on the contaminant distribution and groundwater quality. These wells have been separated into four lines that provide specific information to this *Plan* (Figure 2-2). These lines are as follows:

- The first and second lines of monitoring wells assess the area impacted by contaminated groundwater migrating from the quarry and are sampled to establish trends in contaminant concentrations.
- The third line of wells monitors the alluvial materials south of the slough. These wells are generally unaffected by the quarry and are monitored as the first line of warning for potential migration of uranium migrating south of the slough and to determine the occurrence of upward trends in uranium levels.



• The fourth line of wells monitors the same portion of the alluvial aquifer that supplies the well field. These wells are sampled to detect contaminants in the productive portions of the alluvial aquifer and to determine the occurrence of upward trends in uranium levels.

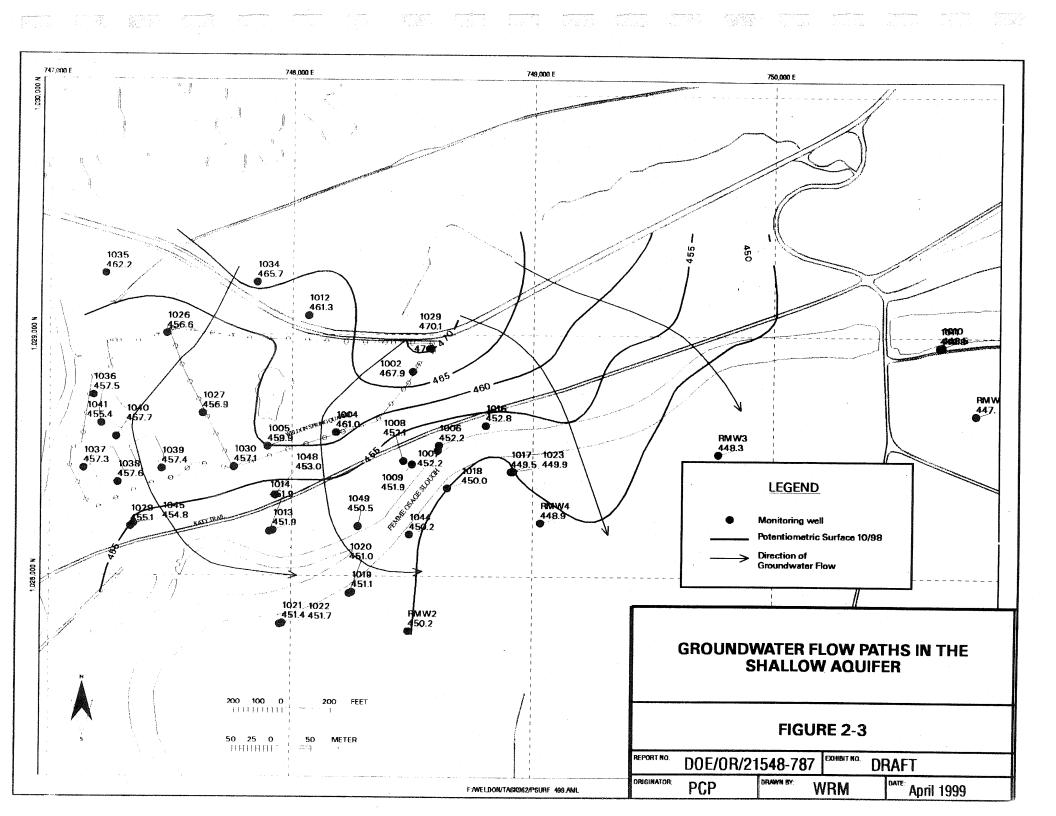
Lateral groundwater flow in the bedrock near the quarry is predominantly to the south, toward the Missouri River alluvium (Figure 2-3). Flow in the Missouri River alluvial aquifer south of the quarry generally is southeast to east, due to the gradient imposed by the Missouri River. A typically closed cone of depression resulting from the production wells in the St. Charles County well field captures groundwater flow. The position of this depression varies depending on the stage of the river and the specific wells being utilized for water production (Ref. 12).

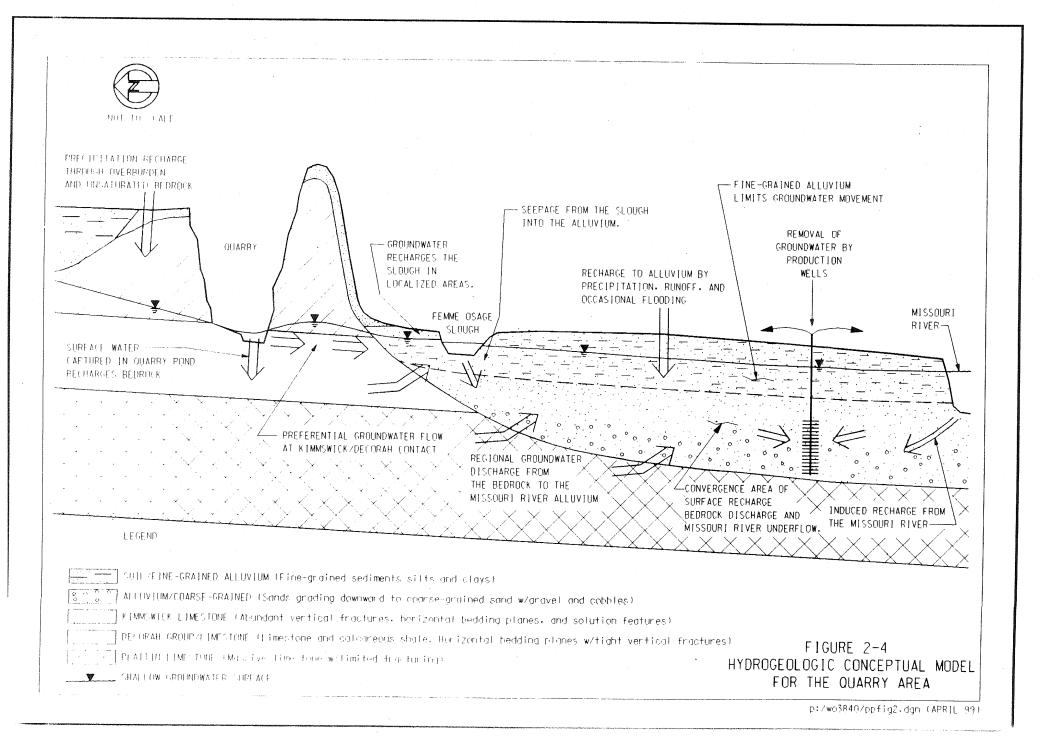
Groundwater modeling has been performed to assess the hydrogeologic system of the well field area in order to predict contaminant movement and potential impacts to the well field. Calculations and models utilize known and estimated values of aquifer dimensions and properties, total water budget, and contaminant characteristics within the study area. Information regarding calculations and models is provided in Appendix A.

Water level measurements in nested wells and piezometers indicate differences in the hydraulic head. In the alluvial aquifer north and immediately south of the slough, the hydraulic head decreases with depth, indicating downward movement of groundwater. In the same area, the hydraulic head in the underlying bedrock units is typically higher than, or equal to the head in the overlying alluvium indicating upward flow (discharge) from the bedrock. These two flows likely converge in the coarse-grained materials at the base of the alluvium and flow laterally toward the Missouri River. A conceptual model of the groundwater flow in the vicinity of the quarry is depicted in Figure 2-4.

Monitoring locations for the long-term monitoring program will be selected to achieve the following criteria:

- Monitor changes and establish trends in contaminant levels in the area of known impact.
- Monitor migration pathways from north of the slough to south of the slough.
- Provide water quality data from the productive portions of the Missouri River alluvium
- Monitor the geochemistry of the shallow aquifer in the area of known impact.





Each existing monitoring well and any proposed monitoring wells will be evaluated against the above criteria in order to optimize the monitoring network to fulfill this *Plan*. The results of this comparison are presented in Appendix B.

2.3 Monitoring Parameters

The contaminants of concern identified in quarry groundwater north of the slough are uranium and nitroaromatic compounds. These contaminants were derived from contaminated bulk wastes that were previously disposed of in the quarry. Although other contaminants were present in quarry bulk wastes, uranium and nitroaromatic compounds are more soluble and were leached from the bulk wastes into the shallow groundwater.

The geochemical characteristics of the aquifer affect the nature and extent of uranium contamination. In the groundwater north of the slough, causes for chemical variability can be attributed to changes in the pH and oxidation potential (Eh). Changes in these parameters could result in the remobilization of constituents that were previously precipitated under differing conditions.

Monitored parameters will be selected to meet the following criteria:

- Parameters that are primary contaminants in the quarry groundwater.
- Parameters that characterize or indicate changes in the geochemistry of the shallow aquifer.

The long-term monitoring program will sample for uranium and nitroaromatic compounds (1,3,5-trinitrobenzene (TNB), 1,3-dinitrobenzene (DNB), 2,4,6-trinitrotoluene (TNT), 2,4-dinitrotoluene (DNT), 2,6-DNT, and nitrobenzene). Geochemical parameters that will be monitored include pH, Eh, sulfate, and iron (total, Fe²⁺, and Fe³⁺).

2.4 Monitoring Frequency

Groundwater monitoring has been performed in the quarry area on a routine basis since 1986. Data from over a 10-year period have been evaluated to determine the nature and extent of contamination. The horizontal and vertical extent of groundwater contamination at the QROU has remained nearly constant over the past 13 years of monitoring (1986 to present), although concentrations have exhibited downward trends since bulk waste removal. Statistical analysis of the data, performed on at least a biannual basis, has indicated that contaminant levels do not exhibit seasonal variability.

The criteria for development of the monitoring frequency are:

- Each location will be sampled at a frequency that will indicate changes in the contaminant distribution or the natural chemistry of the aquifer in a timeframe that will allow for adequate response.
- Sampling will be sufficiently frequent to provide data for the statistical analysis outlined in Section 2.6.

Geochemical sampling will be performed at the same frequency as contaminant sampling both north and south of the slough.

2.4.1 Groundwater North of the Slough

Groundwater north of the slough will be sampled on a quarterly basis to provide sufficient data to accomplish the following:

- Establish trends in contaminant levels at each location
- Establish the percentile of data obtained from north of the slough that is below the threshold level of 300 pCi/l for uranium for a monitoring year.
- Establish the percentile of data obtained from north of the slough that is below the threshold level of 0.11 μ g/l for 2,4-DNT for a monitoring year.

2.4.2 Groundwater South of the Slough

Modeling was used to establish a practical sampling frequency for groundwater south of the slough based on the migration times for uranium and nitroaromatic compounds between each line of wells (Appendix A). Annual sampling at the monitoring wells has been determined to be an adequate frequency for the detection of uranium and nitroaromatic compounds and affords time to implement any actions based on changes in contaminant levels.

2.5 Sampling and Analysis Methods

Groundwater will be sampled using methods that will ensure that representative and comparable samples are obtained for review and trend analysis. The sampling methods will meet the following criteria:

• Samples are representative of the shallow aquifer at each location.

- Samples are comparable with existing data from each location.
- Samples are comparable with other locations collected during the same sampling event.

The Sample Management Guide (Ref. 13) establishes data quality requirements that will be used for data obtained under this Plan. Standard operating procedures (SOPs) have been developed to provide consistency in sample collection methodology and documentation of environmental activities. The SOPs identified in Table 2-2 will be complied with for the monitoring activities in this Plan.

Table 2-2 Applicable Standard Operating Procedures for Groundwater Monitoring

ACTIVITY	STANDARD OPERATING PROCEDURES		
Field Logbooks	ES&H 1.1.4, Logbook Procedure		
Field Equipment Calibration	ES&H 4.5.1, pH and Temperature Measurements in Water		
•	ES&H 4.5.2, Specific Conductance Measurements in Water ES&H 4.5.9, Operation and Calibration of YSI Follow-through Cell System		
Field Measurements	ES&H 4.5.1, pH and Temperature Measurements in Water ES&H 4.5.2, Specific Conductance Measurements in Water ES&H 4.5.5, Measurement of Specific Ions in Water ES&H 4.5.9, Operation and Calibration of YSI Follow-through Cell System ES&H 4.3.2, Groundwater Level Monitoring and Well Integrity		
Sample Identification	Inspections ES&H 4.1.1, Numbering System for Environmental Samples and Sampling Locations		
Sample Collection, Preparation, and Preservation	ES&H 4.4.1, Groundwater Sampling RC-19s, Hazardous material/Sample Transportation Activity (HMSTA) Operations		
Chain of Custody	ES&H 4.1.2, Initiation, Generation, and Transfer of Environmental Chain Of Custody		
Sample Equipment Decontamination	ES&H 4.1.3, Sampling Equipment Decontamination RC-18, Handling and Disposition of Site Generated Waste		
Analytical Procedures	Applicable standards required by DOE and EPA Quality Assurance Project Plan (Ref. 28) and specific SOPs required with laboratory contracts.		
Data Review	ES&H 1.1.7, Environmental Data Review and Above-Normal Data Reporting ES&H 4.9.1, Environmental Monitoring Data Verification ES&H 4.9.2, Environmental Monitoring Data Validation		

These existing standard operating procedures (SOPs) will be implemented to maintain comparability of the data. These operating procedures outline the use of dedicated sampling equipment for each monitoring well to ensure that samples are representative of each location and to prevent cross-contamination with other locations.

Samples will be analyzed using consistent methods for comparability with historical sampling. A summary of the present analytical methods for groundwater at the Weldon Spring site is presented in Table 2-3.

Table 2-3 Analytical Methods for Groundwater

PARAMETER	METHODS	
Uranium, total	Fluorimetry or KPA methodology	
Nitroaromatic Compounds	US Army Environmental Hygiene Agency methodology	
Sulfate	USEPA 300 or EPA 375 methodology	
iron, total	USEPA Contract Laboratory Program (CLP)	
Iron, 2+	Total Laboratory (170 graffit (OE)	
pH	ES&H 4.5.1,	
Eh	ES&H 4.5.2.	

Quality control samples will be collected to ensure consistent and accurate performance of sample collection and laboratory analysis. Table 2-4 provides a summary list of the quality control samples that wil! be collected to support this effort.

Table 2-4 Field Quality Control Sample Summary

QC SAMPLE TYPE	FREQUENCY	PURPOSE
Field Replicate (FR)	1 per 20	Assess matrix inter-laboratory and field operations variability.
Matrix Duplicate (DU)	1 per 20	Assess matrix and possible inter- laboratory variability
Matrix Spike (MS)/Matrix Spike Duplicate (MD)	1 per 20	Assess matrix and possible inter- laboratory variability

2.6 Interpretation of Results

The monitoring approaches for north and south of the slough have been designed to accomplish different objectives (see Section 2.1); therefore, the interpretation of the data from each area will be discussed separately.

2.6.1 Groundwater Monitoring North of the Sough

Data obtained from the network of wells monitoring the groundwater north of the slough will be evaluated on a yearly basis to determine if the 90^{th} percentile of the data from that year is below the threshold level of 300 pCi/l for uranium and 0.11 µg/l for 2,4-DNT. This analysis will be performed to determine whether:

1. The groundwater being sampled has attained the threshold levels.

- 2. The groundwater has not attain the threshold levels.
- 3. More data are required to make a decision.

If more data are required, an additional year of data will be collected before the next statistical analysis is performed.

Data obtained from wells in the long-term monitoring network will be used to augment the existing database. These data will be used in trend analysis for uranium and nitroaromatic compounds. Standard trending analysis methods (nonparametric Mann-Kendall test) will be utilized for the determination of increasing, unchanged, or decreasing trends at each location north of the slough. This method has been selected due to its previous use in trending analysis for quarry environmental monitoring data (Ref. 10).

It will be recommended that long-term monitoring activities be concluded for this operable unit if it is determined that the levels north of the slough are below the threshold levels and that stationary or downward trends for uranium and 2,4-DNT have been determined for each monitoring location. If upward trends in uranium or 2,4-DNT are determined, monitoring will continue for an additional year to evaluate these trends. Recommendations may be made to delete uranium or 2,4-DNT from the monitoring if either of these parameters meets the necessary monitoring criteria before the other.

2.6.2 Groundwater Monitoring South of the Slough

Data will be evaluated to ensure that the uranium levels in the groundwater south of the slough remain below the threshold value of 30 pCi/l. If the 90th percentile of the data from that year remains below the threshold level of 30 pCi/l, monitoring will continue until the criteria for the groundwater north of the slough have been attained. If it is determined that the threshold value has been exceeded, actions outlined in Section 2.8 will be assessed.

Data obtained from wells south of the slough will be used to augment the existing database and will be used in statistical analysis. Statistical tests will be performed to maintain that trends remain unchanged or are decreasing and those levels remain below the threshold value.

2.6.3 Geochemical Monitoring of the Shallow Aquifer

Data obtained from wells south of the slough will be used to augment the existing geochemical database. Data will be compared to historical data to monitor for changes in the geochemistry of the shallow aquifer. Changes or trends (increasing or decreasing) in the data will be used as indicators of potential changes that could result in contaminant migration. Evaluation of the contaminant monitoring program may be performed based on changes in the geochemical data.

2.7 Monitoring Well Design Criteria

As outlined in the *Proposed Plan* (Ref. 7), monitoring would continue in perpetuity or until judged unnecessary based on a review of the data. The minimum design life for monitoring wells is expected to be 30 years.

The criteria for the design of the wells are as follows:

- Monitor the specified intervals or zones.
- Well materials are compatible with environment.
- Meet the requirements outlined in 20 CSR 23, The Missouri Well Drillers' Law.

The majority of the wells to be used for this monitoring are existing wells that meet the above criteria. All proposed monitoring wells will be designed to ensure they meet the above criteria.

2.8 Monitoring Plan Actions

If a consistently upward trend in uranium or 2,4-DNT levels is detected in wells immediately north or south of the slough, investigation of the source and transport mechanism for the increasing levels will be performed. This may include performance of hydrogeologic and/or contaminant investigations, installation of additional monitoring wells, or increased sampling frequency of existing monitoring wells.

In the event it is determined that groundwater south of the slough no longer remains below the threshold value of 30 pCi/l for uranium, notifications will be made to the Missouri Department of Natural Resources, and St. Charles County. If the increased value is determined to be valid, the potential for significant impacts to the well field and the alluvial aquifer will be reevaluated (Ref. 1). This evaluation may include:

- Resampling of the locations in question and other potentially affected locations, and submittal of samples to analytical laboratories for expedited analyses.
- Increased frequency of sample collection.
- Performance of hydrogeologic and/or contaminant investigations to identify migration pathways.
- Installation of additional monitoring wells, if deemed appropriate and necessary.

- Groundwater modeling to predict long-term impacts, if deemed appropriate or necessary.
- A risk evaluation consistent with methods outlined under Comprehensive Environmental Response, Compensation and Liability Act (CERCLA).
- Identification of applicable or relevant and appropriate requirements (ARARs).
- A determination of the need for any groundwater remediation.
- Implementation of contingencies outlined in the Well Field Contingency Plan (Ref. 9).

2.9 Data Reporting and Documentation

Environmental monitoring results, including statistical analysis, will be reported on an annual basis in the annual report for the Weldon Spring site, which will summarize the long-term monitoring and maintenance activities for the previous year. This information will be compiled in a report for the 5-year review, and conclusions regarding the continuation or conclusion of this monitoring activity will be made.

3. INSTITUTIONAL CONTROLS

Institutional controls will be necessary to prevent groundwater usage inconsistent with recreational uses, or uses that would adversely affect contaminant migration. Uranium in groundwater north of the slough ranges from 2,200 pCi/l to less than 1 pCi/l and 2,4-dinitrotoluene (2,4-DNT) ranges from 0.23 μ g/l to less than 0.03 μ g/l. Uranium levels south of the slough are within background ranges (less than 10 pCi/l). Nitroaromatic compounds have not been detected in groundwater south of the slough.

3.1 Affected Area

Institutional controls will be imposed in the area of known uranium impact and a 500-ft buffer zone (Figure 3-1). Controls in this zone will prohibit the extraction or collection of groundwater for consumption, irrigation, or other purposes.

3.2 Agreements

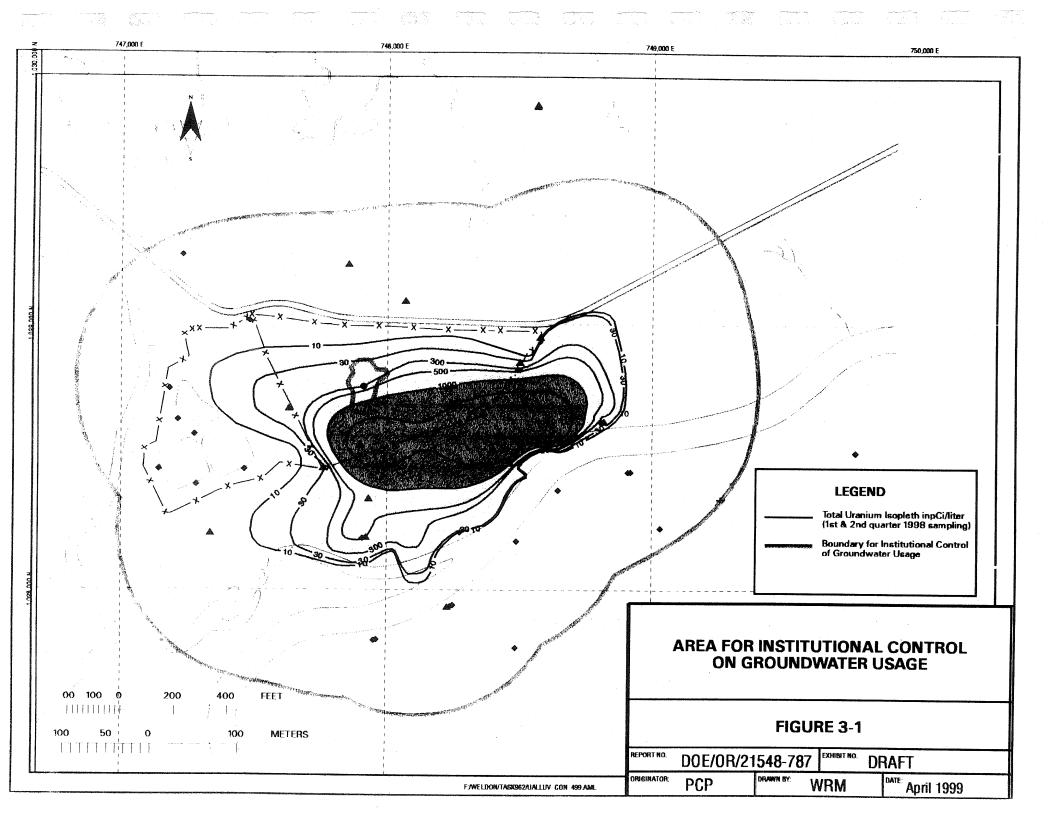
Institutional controls will be employed and enforced through agreements between the U.S. Department of Energy and the affected landowners. The objectives for these controls are to:

- Limit access to groundwater
- Prevent uses that will impact contaminant distribution.
- Prevent altering of the geochemistry of the aquifer.

These controls will be developed in coordination with the affected landowners, Missouri Department of Natural Resources, and the Missouri Department of Conservation. The terms of the institutional controls may be established in a written agreement, such as a license agreement, memorandum of understanding, or deed restriction. These agreements will be summarized in the Stewardship Plan for the Weldon Spring Site (Ref. 14), which is in the draft stages of development. This plan will summarize all agreements, responsible parties, and actions that will be implemented long-term at the chemical plant and quarry.

3.3 Reevaluation of Institutional Controls

Restrictions on groundwater usage will be employed to prevent usage inconsistent with the recreational scenario until threshold levels have been achieved (see Section 2). After completion of the monitoring activities, institutional controls on groundwater will be reevaluated.



Following completion of the monitoring activities, an assessment of the residual risks based on actual groundwater concentrations will be performed to determine the need for any future groundwater usage restrictions. This assessment will take into account any changes in the system (i.e., relocation/removal of production wells, changes in land use) to protect human health and the environment for the long term. Relocation of the production wells or closure of the water treatment facility would result in the removal of institutional controls on groundwater usage. As outlined in the *Record of Decision* (Ref. 1), 5-year reviews will be conducted to evaluate the conditions at the quarry and to ensure that the remedy provides adequate protection of human health and the environment.

4. FIELD STUDIES IN SUPPORT OF THE SELECTED REMEDY

The selected remedy in the *Record of Decision* (Ref. 1) outlines the performance of two field studies to support the decision for long-term monitoring of groundwater. These field studies will consist of the installation and operation of an interceptor trench and hydrologic and geochemical sampling within the area of uranium impact to verify the effectiveness of uranium removal by groundwater extraction methods, as presented in the *Feasibility Study* (Ref. 6). These studies are planned for the following reasons: (1) the presence of significant levels of contamination in quarry groundwater north of the slough, which is in close proximity to the St. Charles County well field, and (2) the reliance on natural systems to limit potential exposures. The results from these studies will be used to evaluate the effectiveness and benefits of removing the uranium from the groundwater north of the slough.

4.1 Interceptor Trench

Several configurations of an interceptor trench were evaluated in the *Feasibility Study*. The most effective configuration was determined to be a trench located near the center of the uranium plume. This configuration could result in expedited removal of the highest uranium concentrations. Groundwater modeling using analytical methods indicated that this extraction system had the potential to reduce the mass of uranium in groundwater north of the slough by 8% to 10% over a 2-year operating period (Ref. 6). This removal would constitute a small reduction of the total uranium contamination present and would not provide a measurable increase in protectiveness over the foreseeable future.

The objective of this field study is to confirm the predictive model on uranium removal from the shallow aquifer using actual field data. If the performance of the trench is less effective or within the specified performance goals ($\leq 10\%$ of the mass of uranium removed within the area of influence of the trench within a 2-year testing period), further evaluation regarding groundwater in this area will not be necessary. If the performance of the trench exceeds the specified goals ($\geq 10\%$ of the mass of uranium removed within the area of influence of the trench within a 2-year testing period), the effectiveness or benefit of groundwater extraction will be reevaluated.

4.1.1 Design

The design criteria are summarized in the Design Criteria for Work Package 508, Architect Engineer Service VI, Task 6, Revision 1 (Ref. 15) and supporting documents. The design, as well as construction documents, will be summarized in Work Package 515, Quarry Interceptor Trench System.

The interceptor trench will be constructed to intersect a representative cross section of alluvial material and will be optimally located to extract groundwater in areas with high uranium contamination. Specific criteria used for siting the interceptor trench are:

- Bound the hydraulic variations present north of the slough.
- Bound the contaminant variation present north of the slough.
- Extract groundwater over the full thickness of the alluvial materials.
- Prevent dewatering of the slough and extraction of unnecessarily large volumes of water.

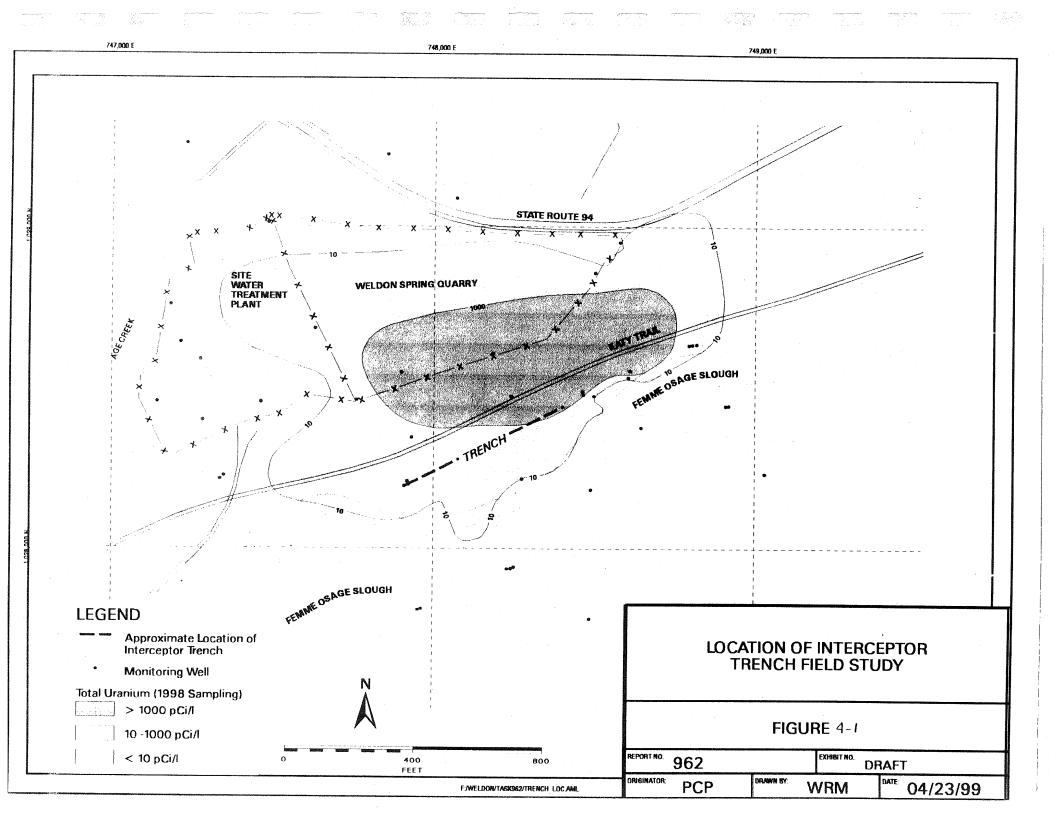
The interceptor trench will be located in the alluvial aquifer south of the Katy Trail and north of the slough and will be approximately 550 ft long (Figure 4-1). The trench will be constructed through the entire thickness of the alluvial materials. The trench will be sufficiently wide to accommodate filter media and collection piping and pumps, with a minimum width of 12 in. The orientation of the trench will be perpendicular to the general groundwater flow direction.

The trench will extend to the top of the bedrock with sumps located at depressions in the bedrock topography. The trench will be backfilled with a permeable filter media, which will be covered with a lower permeability material to prevent direct communication between the alluvial aquifer and the atmosphere and to prevent surface water from entering the trench. Pumps and piping will be enclosed below grade to prevent vandalism and to be unobtrusive.

The trench will provide hydraulic capture of uranium-contaminated groundwater in the alluvial aquifer along its length. The pumping rate will be optimized to provide continuous pumping without dewatering of the alluvial materials. It is estimated that the pumping rate from the trench will be approximately 10 gpm, based on calculations presented in the *Feasibility Study* (Ref. 6). The actual pumping rate will be determined from the performance of this field study; therefore, pumps capable of variable rates will be utilized.

Water produced from the interceptor trench will be routed below grade to the quarry water treatment plant. Conveyance piping to the plant will be double-walled and have a leak detection system. The water treated at the plant will be discharged to the Missouri River using the existing effluent pipeline. A means of discharging the water from the trench without being processed through the treatment plant will be designed.

The trench and conveyance system will be capable of year-round operation, including during flood conditions. The design life of the trench and conveyance systems will be 5 years.



4.1.2 Monitoring

The performance of the trench will be monitored to determine: (1) the efficiency of uranium removal from the aquifer and (2) the area of influence of the trench. Levels of nitroaromatic compounds will also be monitored. Effluent from the trench, groundwater samples, and measurement of the static water levels in the vicinity of the trench will be used to assess the performance of the trench system.

The trench will be designed to allow sampling of the effluent from the trench and from each sump within the trench to evaluate the mass of uranium removed from the aquifer. Operational samples will be collected from the trench on at least a weekly basis. The water level within each sump will be measured on at least a weekly basis to evaluate the drawdown in the aquifer.

Observation wells will be installed in close proximity to the trench to monitor the effects of the trench operation on the water quality of the alluvial aquifer and groundwater flow directions. Groundwater samples will be collected on a monthly basis from these wells. Groundwater will also be sampled from the nearby monitoring wells on a quarterly basis as outlined in the long-term monitoring section of this plan (see Section 2). Static water level measurements will be taken on at least a biweekly basis to monitor the effects of groundwater withdrawal on the aquifer.

The observation wells will be screened through the entire thickness of the alluvial aquifer in order to simulate the levels of uranium being extracted by the trench and to obtain the water level of the unconfined shallow aquifer. The wells will be constructed using polyvinyl chloride (PVC) materials. These wells will be constructed in accordance with 10 CSR 23, the *Missouri Well Driller's Law*.

4.1.3 Data Evaluation

The system will be evaluated and monitored for up to two years. Data will be collected from the trench (i.e., volume of water extracted and uranium and nitroaromatic compound levels) and from observation wells installed in the area of influence of the trench. This data will be combined with other data collected as part of the hydrogeologic field data to evaluate the effectiveness of the trench versus predetermined performance goals.

The interceptor trench is expected to remove only a percentage of the uranium in the groundwater after a specified operational period. The efficiency of the system depends on three factors:

- The initial mass of uranium present in the area of influence of the trench.
- The volume of groundwater extracted

• The concentration of uranium in the effluent.

The total mass of uranium present in the contaminated zone will be assumed to be equal to the value 8×10^{11} pCi (Ref. 4). The interceptor trench will not have an influence over the entire area of the plume; therefore, only a percentage of the total mass of uranium will be considered to determine the effectiveness of its operation. The percentage of the plume that will be influenced by the operation of the trench is 27%; therefore, the initial total mass of uranium to be used in this study is 2×10^{11} pCi.

The rate of uranium removal from the trench will be derived from measurements of the uranium concentration and the volumetric discharge rate from the trench over time. The ratio of the mass of uranium removed to the initial total mass present will provide an indication of the trench efficiency. A curve of the mass of uranium removed versus time can be constructed. This curve may be used to extrapolate the amount of uranium that will be removed during the two-year operational period of the trench. It is anticipated that the removal rate of uranium will be largest at the beginning of trench operations, and then is expected to decrease and approach a constant value with time.

If the results for the uranium removal indicate that 10% or less of the total uranium present in the area of influence $(2 \times 10^{11} \, \text{pCi})$ will be removed over the 2-year operational period, it may be possible to terminate operation of the trench prior to the full testing period. A steep decline in groundwater extraction rates, uranium levels, or both would trigger an evaluation of the effectiveness of the trench prior to completion of the 2-year period. The results of the study to that point would be compiled and conclusions regarding the continued performance of the field study would be presented in a project completion report (See Section 12.1.7).

At the completion of the 2-year period, the data from the trench will be compiled to determine the effectiveness of an interceptor trench for the removal of uranium from the shallow aquifer. Data to be presented will include:

- Curve of the mass of uranium removed.
- Curves of the volume of groundwater extracted.
- Static water level data from observation wells and nearby monitoring wells.
- Summary of analytical data for uranium and nitroaromatic compounds from the study area (both from the trench and nearby observation wells).
- Summary of the total mass of uranium removed from the aquifer.

- Summary of the total volume of groundwater extracted from the aquifer.
- Conclusions regarding the performance of the interceptor trench system.

A completion report presenting the above information will be used to document the decision to consider the field study complete. The public will be made aware of the findings of this study through a published notification summarizing the results of the evaluation of the system.

4.2 Hydrogeological Field Studies

Geologic, hydrologic, and geochemical field studies will be performed to provide data from within the area north of the slough where uranium impact has occurred in the groundwater. This site-specific data will be used to supplement and verify the current model regarding the hydrogeologic and geochemical site characteristics that dictate fate and transport and potential remediation of uranium in this area.

The sampling and analysis methods for these tasks are or will be provided in the *Hydrogeological Characterization Sampling Plan in Support of the QROU Field Studies* (Ref. 16) and the (Ref. 35). Fieldwork associated with the hydrogeological characterization was completed in February 1999. It is expected that the geochemical characterization will be performed during the summer of 1999. Closure reports will be prepared after completion of each of these activities that will discuss the field efforts and results of this sampling.

4.2.1 Geologic Characterization

The objectives of the geologic characterization were to:

- Further define the lateral and vertical distribution of the differing fine-grained materials north of the slough.
- Provide a detailed description of the underlying Decorah Group.
- Provide information for stratigraphic correlation of hydrologic and geochemical characteristics from characterized portions of the shallow aquifer to the remaining portions north of the slough.

Geologic information has been obtained through borings advanced through the soil and at some locations into the upper bedrock. Information included lithologic and geologic descriptions, fracture density, mineralogy, secondary mineralogy (i.e. iron oxides, manganese hydroxides, etc.), organic content, identification of formation contacts, thickness of the Decorah

Group, and depth to bedrock. Emphasis was placed on identifying zones of preferential groundwater movement (fractures, weathering, sand zones, contacts between units) and secondary mineralogy of the aquifer matrix. This data will be summarized in the Completion Report for Hydrogeological Field Studies in Support of the QROU.

4.2.2 Geochemical Characterization

The objectives of the geochemical characterization are to:

- Assess the natural conditions of the aquifer system, which attenuates uranium in groundwater north of the slough.
- Estimate distribution coefficients for differing locations and material types north of the slough.
- Characterize the oxidation potential within the aquifer.
- Provide additional supporting evidence for the presence of a reduction zone north of the slough.

Soil and groundwater samples will be collected throughout the shallow aquifer north of the slough to assess the natural conditions of the aquifer that attenuate or retard dissolved uranium in groundwater. The notable decrease of uranium over a short distance north of the slough indicates that processes other than dilution are reducing the amount of dissolved uranium. The processes to be investigated are sorption and reduction (precipitation) of uranium.

Sorption is a generic term describing contaminant removal from solution, and includes ion exchange, specific adsorption to mineral surfaces and/or organic matter, or other processes. Contaminant sorption to soil or the aquifer matrix from groundwater is commonly quantified in terms of a distribution coefficient (Kd). Limited site-specific Kd data is available for locations both north and south of the slough (Ref. 6). Additional sampling of soil and groundwater will be performed in the fine-grained materials north of the slough to establish the variability of Kds in this area.

The geochemical characteristics of uranium and the aquifer affect its extent in groundwater. Removal of contaminants from groundwater via precipitation to solid phases typically results from changes in geochemical conditions, which cause one or more contaminants to exceed their solubility limit in water. Uranium is soluble under oxidizing conditions and precipitates into solid phases under reducing conditions (Ref. 4). Sampling of groundwater in the area north of the slough will be performed to identify the variation of the oxidation potential (Eh) of the aquifer in this area. Direct measurements of the Eh will be performed to establish the

horizontal and vertical variations. Analysis of groundwater for oxidation/reduction pairs and Eh will be used in establishing the geochemical constraints of uranium migration in this area.

4.2.3 Hydrologic Characterization

The objectives of the hydrologic characterization were to:

- Determine the variation in aquifer parameters due to the heterogeneity of the fine-grained alluvium.
- Identify zones within the bedrock that facilitate the migration of uraniumcontaminated groundwater.

Single-well hydraulic conductivity tests (slug tests) and pressure tests (packer tests) were performed in the borings drilled for the geologic characterization. Slug tests determine the hydraulic conductivity of the saturated zone around a well screen or intake. The results from these tests can be used to determine aquifer heterogeneity. Packer tests are used to provide hydraulic conductivity information for competent bedrock. The results from these tests will be used to identify zones within the bedrock aquifer that could be potential groundwater migration pathways and will be documented in the Completion Report for Hydrogeological Field Studies in Support of the QROU.

5. QUARRY PROPER SOILS

The Record of Decision (Ref. 1) identified a need to define the extent of radiological soil contamination at the northeast slope and ditch area near the transfer station (Figure 5-1). If contaminant levels are found to be unacceptable following a risk evaluation using additional characterization data, it was proposed to address these areas under a subsequent response action.

The northeast corner will not be accessible for characterization until restoration activities (see Section 6) at the quarry proper are performed. The ditch area near the transfer station will be characterized prior to restoration activities. Due to sequencing of quarry restoration, it has been decided to excavate radiologically contaminated soils in the ditch area based on the characterization data.

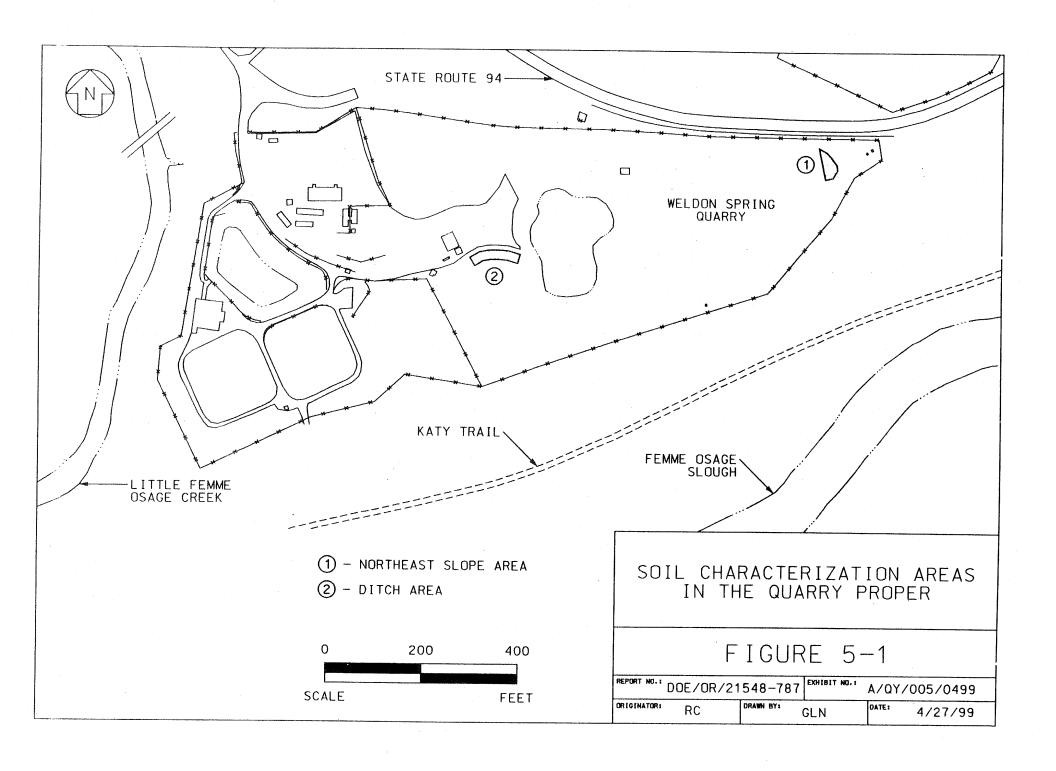
5.1 Northeast Corner

The northeast slope area was partially remediated during the last phases of bulk waste removal, but due to limitations of the equipment, some areas were not accessible for contaminated soil removal. Prior to remediation, characterization indicated the northeast slope contained small isolated pockets of concentrated radium- and thorium-rich material interspersed within the disturbed native soil. The remains of a buried drum containing radium wastes were discovered near this area and were removed. After completion of bulk waste removal, samples were collected from the north rim near the northeast corner of the quarry, which indicated elevated levels of radium and thorium. Elevated exposure readings using direct reading survey instruments and thoron monitoring indicate that additional contamination is likely present.

5.1.1 Characterization

Presently the northeast slope area is inaccessible; therefore, an exact determination of the sampling area cannot be made. After access is established, the sampling area will be determined through the review of existing data and walkover surveys and the sampling locations and intervals to fully characterize this area will be determined. Sampling will be developed and implemented that will fulfill the following criteria:

- Delineate the horizontal extent of Ra-226, Ra-228, and Th-230 contamination in the northeast slope.
- Delineate the vertical extent of Ra-226, Ra-228, and Th-230 contamination in the northeast slope.



- Provide sufficient data to perform risk calculations consistent with the approach discussed in the *Record of Decision* (Ref. 1).
- Provide sufficient data to design excavation limits for contaminated soil removal, if based on the risk calculations, remedial action is necessary.

The sampling requirements and analysis necessary to delineate the lateral and vertical extent of radiological soils contamination will be provided in the Sampling Plan for Radiological Characterization of the Northeast Slope Area of the Weldon Spring Quarry. A closure report will be prepared after completion of this activity that will discuss the field efforts and results of this sampling.

5.1.2 Data Evaluation

As outlined in the Record of Decision (Ref. 1), risk calculations will be performed consistent with the approach presented in the Baseline Risk Assessment (Ref. 5), to include these additional data points. Data will be used to evaluate risk to a recreational visitor, consistent with the scenario identified for this operable unit. The reevaluation of the risk, based on the additional data, will be presented in the Reevaluation of Risk for the Northeast Slope Area of the Quarry Residuals Operable Unit.

If it is determined that the risk from these soils is unacceptable, this area will be addressed under a subsequent response action. If a response action is necessary, the data generated as a result of this sampling will be used to design excavation limits for remediation. The cleanup criteria for radionuclides presented in the Record of Decision for Remedial Action at the Chemical Plant Area of the Weldon Spring Site (Ref. 8) will be applied (Table 5-1).

Table 5-1 Cleanup Criteria for Selected Radionuclides

Surface Criteria (1)	Subsurface Criteria (2)
6.2 pCi/a	16.2 pCi/a
6.2 pCi/a	16.2 pCi/g
	16.2 pCi/g
	10.2 pCl/g

Source: Ref. 8

Note: 1 Values apply to contamination within the upper 6 in.

2 Values apply to contamination below 6 in.

At locations were both Ra-226 and Ra-228 are present, the criterion applies to the sum of the concentrations.

5.2 Ditch Area Near the Transfer Station

A small area of residual contamination in a ditch near the entrance of the quarry proper is also present. Results from surface samples (upper 6 in.) indicate elevated levels of radionuclides on the ground surface. These materials were projected to be removed, if necessary, during restoration activities.

5.2.1 Characterization

Four samples were collected from this area during the remedial investigation that indicated surface contamination for Ra-226, Ra-228, isotopic thorium, and uranium (Figure 5-2). Location 816 was sampled to a depth of 3 ft. The remaining three locations were surface samples (0 in. to 6 in.). The range of values for this area is summarized in Table 5-2.

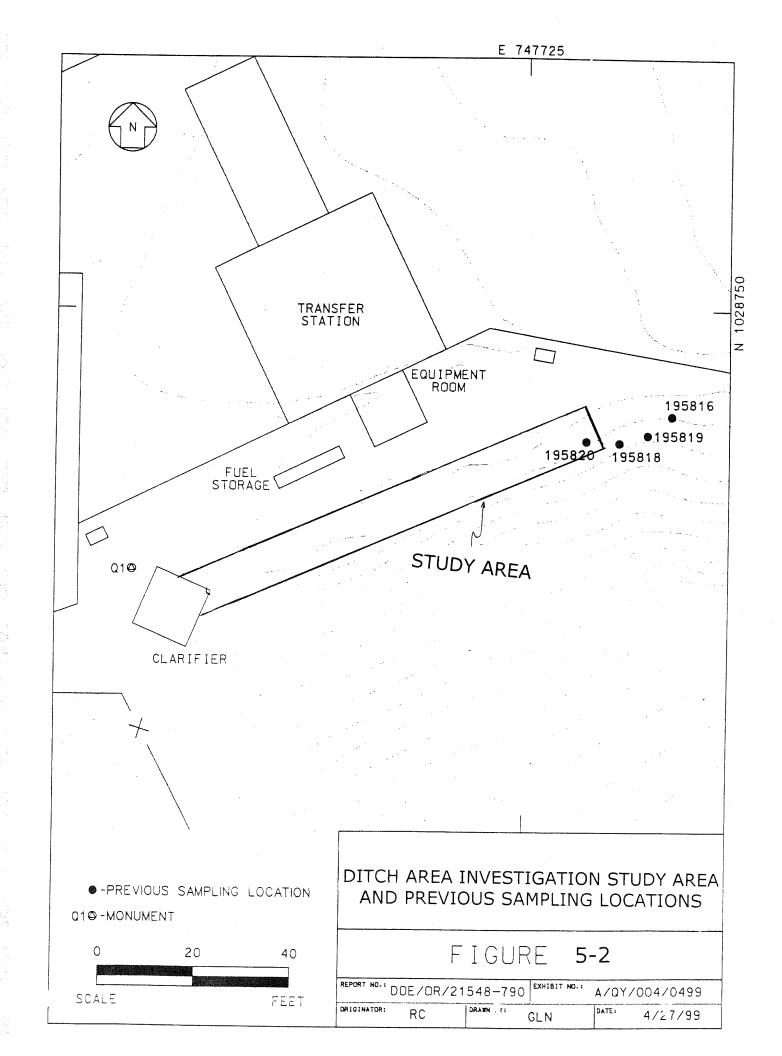
Table 5-2 Ranges for Radiochemical Data from the Ditch Area

MINIMUM (pCi/g)	MAXIMUM (pCi/g) (1)
0.30	26.7
0.16	14.2
0.46	24.1
1.88	566
	25.2
	34.2
	1.4
	36.5
	0.16

Note: 1 All maximum values were detected in sample SO-195820-01

The area that will be investigated (Figure 5-2) extends from the clarifier to Location 820. During bulk waste removal operations, it was documented that the pond water from the quarry overflowed from the clarifier and discharged back into the pond via the ditch. Sampling will be developed and implemented that will fulfill the following objectives:

- Delineate the horizontal extent of radiochemical contamination in the ditch area.
- Delineate the vertical extent of radiochemical contamination in the ditch area.
- Provide sufficient data to design excavation limits for contaminated soil removal based on subsurface criteria levels presented in the Record of Decision for Remedial Action at the Chemical Plant Area of the Weldon Spring Site (Ref. 8).



A walkover survey will be performed initially to identify locations for biased sampling. It cannot be assumed that radium and thorium wastes are commingled; therefore, field screening cannot be used as the only method to determined sampling locations. Samples will be collected on 20-ft intervals along the centerline of the ditch, from the ground surface to the top of bedrock, which is not expected to be greater than 3 ft in depth at this location. Based on the results from these locations, discrete areas of the ditch will be completely characterized.

The sampling requirements and analysis necessary to delineate the lateral and vertical extent of radiological soils contamination will be provided in the Sampling Plan for Radiological Characterization of the Ditch Area at the Weldon Spring Quarry. A closure report will be prepared after completion of this activity that will discuss the field efforts and results of this sampling.

5.2.2 Excavation Activities

Excavation limits will be developed and documented in Work Package 513, Quarry Restoration. These limits will be based on the characterization data outlined in Section 5.2.1. Excavation of soils exceeding subsurface criteria presented in Table 5-1 will be performed during restoration activities in the quarry proper. Subsurface criteria have been selected because this area will be backfilled with approximately 10 ft of fill material at the completion of the restoration activities.

A post-excavation evaluation will be performed after removal of the soils to engineered excavation limits. This evaluation will consist of sampling of the remaining soil surface. Surface soil samples (0 in to 6 in.) will be collected on a 30-ft by 30-ft grid, which will be oriented over the excavation to maximize the number of samples collected from the excavation area. These samples will be analyzed for Ra-226, Ra-228, Th-230, and U-238 to obtain levels that will remain after removal of impacted soils.

5.2.3 Data Evaluation

The removal of impacted soils will be considered complete if the average of the data for each parameter obtained from the excavation is less than the subsurface criteria presented in Table 5-1 and no locations greater than 1.5 times background have been indicated from walkover surveys. If the average is greater than the subsurface criteria presented in Table 5-1, the locations with the highest level for the parameter in question will be excavated and new samples obtained for re-evaluation. Locations exceeding 1.5 times background will be excavated.

6. QUARRY RECLAMATION

Reclamation of the quarry area will be performed under two projects. The design criteria for both projects are summarized in the *Design Criteria for Work Package 508*, *Architect/Engineer Service VI*, *Task 4*, *Revision* 0 (Ref. 17) and supporting documents. The design, as well as construction documents, for both of these activities will be provided in the specifications and design drawings for WP-513, *Quarry Proper Restoration* and WP-529, *Quarry Interceptor Trench System Reclamation*.

6.1 Work Package 513, Quarry Proper Restoration

Quarry restoration includes backfilling the quarry, limited restoration of the quarry haul road, removal of existing miscellaneous structures, utilities, and features, and possible removal of potentially contaminated residual soils in the quarry proper. The restoration of the quarry proper will include an intermediate grading plan to allow this work to proceed without impacting the operation of the quarry water treatment plant.

6.1.1 Backfilling of the Quarry Proper

The quarry proper will be restored through backfilling with soil to meet the following criteria:

- Minimize long-term physical hazards associated with the quarry high walls.
- Eliminate ponded water in the quarry.
- Reduce recharge to the groundwater within the quarry.
- Restore the quarry to a natural state.

The most significant hazard associated with the quarry proper is the presence of the highwalls along the north, east, and south sides of the quarry proper. Elevation differences along the highwalls range from 440 ft. to 552 ft. above mean sea level. Backfilling the quarry with any amount of soil will reduce fall hazards associated with this area.

An evaluation of the stability of the quarry highwalls was performed to assess: (1) the height of backfill placement, (2) the potential for slope failures or rock fall hazards after restoration is complete, and (3) the application of protective measures to minimize physical hazards during and after restoration. The highwalls of the quarry consist of hard to moderately hard limestone, which is moderately weathered, and exhibits solutioning along existing discontinuities in the rock mass. The orientation of the bedding planes and the wide spacing between rock joints are favorable conditions for inherent slope stability. Based on observations made during the evaluation, most of the quarry highwalls appear to be in a stable condition; therefore, an extensive rock stabilization program will

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not be required for this project. Small isolated sections along the north quarry wall have been identified as potential minor rockfall areas, primarily during construction activities.

Backfill will be selected and placed in a manner to:

- Minimize settling.
- Minimize the flow of groundwater through the quarry proper.
- Minimize infiltration of precipitation.
- Promote sheet-flow of surface runoff over the top of the backfill.

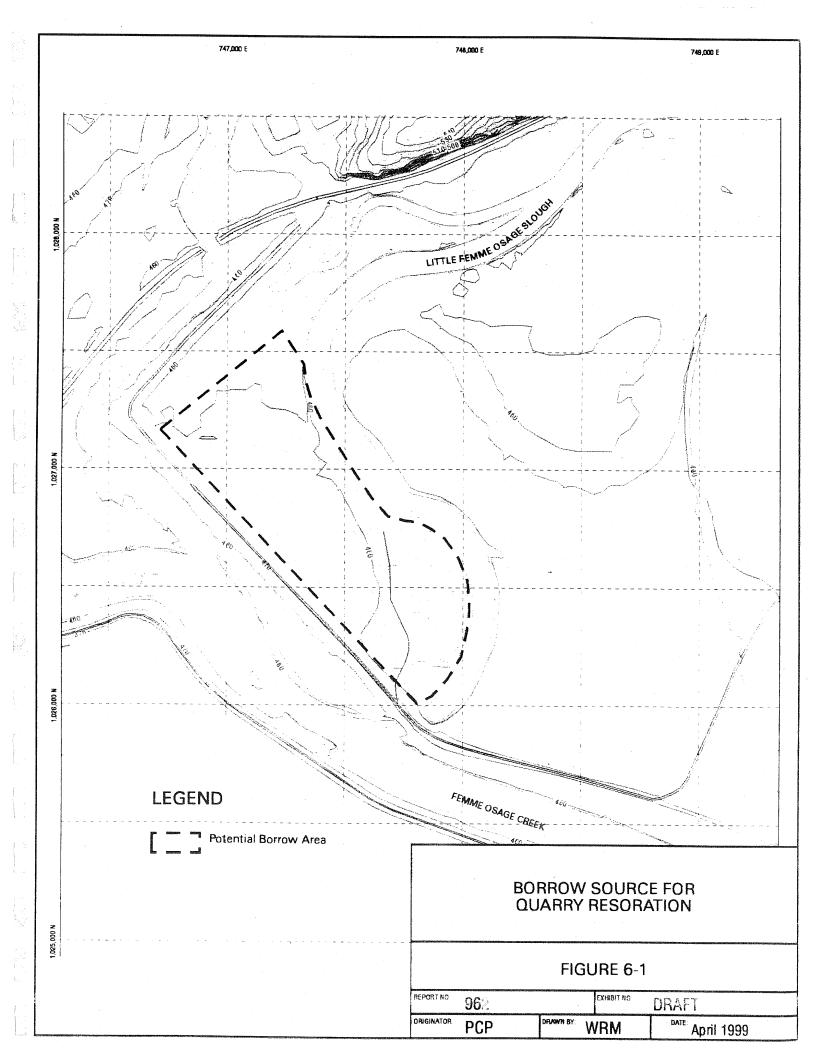
The quarry will be backfilled with a soil material with a lower permeability than the surrounding bedrock to promote regional horizontal groundwater flow around the quarry proper. The permeability of the Kimmswick Limestone is defined as $2x10^{-4}$ cm/sec (Ref. 4). This lower permeability material will be placed to an elevation of 470 ft MSL, which is the modeled high static water level in the quarry. Above this elevation, a common fill material will be used to attain the desired fill elevations. A lower permeability cap, approximately 2 ft. thick, will be placed over the backfill material to minimize infiltration of precipitation and promote sheet flow. Six inches of topsoil will be placed over the cap to allow for vegetative growth.

Borrow materials for backfilling of the quarry proper will be obtained from the Missouri River floodplain, southwest of the quarry (Figure 6-1). Minor amounts of backfill will also be obtained from the quarry staging area. Suitable lower permeability materials are soils that classify as CL and CH in accordance to ASTM D2487, Standard Classification of Soils for Engineering Purposes. Common fill includes all material types except MH, PT, OH, and OL. These materials will be selectively excavated and hauled to the quarry for placement.

The fill materials will be compacted in-place to reduce the possibility of settlement. All fill materials will be compacted to 90% of their respective maximum dry densities. Moisture control will be maintained to accommodate compaction of soils.

Several large aperture fractures are present on the floor and benches of the quarry floor. These large fractures will be filled to reduce the possibility of soil piping and ultimately settlement of the final graded soil surface. Lower permeability clay materials will be used to backfill fractures.

Final grades within the quarry proper will slope from the northeast corner to the Little Femme Osage Creek, with minimal grade changes in the flow path. Placement of materials and final grading will prevent ponding on the final graded surface. The area will be seeded to prevent erosion of the backfill surface and to promote the growth of natural vegetation.



6.1.2 Removal of Facilities Associated with Bulk Waste Removal

As part of the quarry restoration, facilities in the quarry area are to be dismantled/demolished. Major items included are:

- Transfer station and support building (contaminated).
- Aboveground storage tank support slab, dispenser slabs, and associated piping (contaminated).
- Decontamination pad, which includes the pad, sump, and associated piping (contaminated).
- Underground piping from the equalization pond to the quarry pond (contaminated).
- Pavement (asphalt and concrete) (uncontaminated).
- Above ground and underground utilities (water, electric, septic tanks, drain lines) (uncontaminated).

Uncontaminated materials and equipment are to be removed from the quarry area and disposed of at an off-site facility. Contaminated materials and equipment will be segregated into two categories: soil/concrete and other debris. These materials will be hauled to the chemical plant via the quarry haul road for disposal in the on-site disposal cell. Materials will be transported in direct-haul trucks.

6.1.3 Restoration of the Quarry Haul Road

Haul road restoration will require the removal of gates, signs, posts, fencing, and other construction-use features. These materials are uncontaminated and will be removed from the quarry area and disposed of at an off-site facility. The aggregate road surface will not be removed.

6.1.4 Excavation of Potentially Contaminated Soils

A 1-ft envelope of soil will be removed from below and around the sides of contaminated underground piping during the excavation of pipelines. The following piping is considered contaminated:

• Piping between the quarry pond and the equalization basin.

- Piping between the decontamination pad sump and the equalization basin.
- Piping between the shower trailers and the decontamination pad sump.
- Piping between the fuel station aboveground storage tanks and the fuel dispensers.
- Piping between the transfer station and the quarry pond.

Under best management practices, the areas will be scanned during the excavation activities. Locations exceeding 1.5 times background as measured with a NaI (2X2) meter will be evaluated for additional excavation. It is assumed that if leakage were to have occurred, both radiological and chemical contamination would be collocated.

Characterization data from samples collected beneath the decontamination pad slab, adjacent to the decontamination pad sump, beneath the aboveground fuel storage tank slab, and dispenser pads does not indicate impact to soils from the operation of these facilities during the bulk waste removal operations. The samples from the decontamination pad were analyzed for Ra-226, Ra-228, isotopic thorium, U-238, arsenic, lead, nickel, selenium, nitroaromatic compounds, polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs). Samples from beneath the fuel station were sampled for benzene, toluene, ethylbenzene, xylenes (BTEX), and total petroleum hydrocarbons (TPH). Soil is not present beneath the transfer station; therefore, no samples were collected for analysis as outlined in the *Engineering Characterization Sampling Plan for the Quarry Staging Area* (Ref. 18). Data results are summarized in the *Completion Report for the Engineering Characterization of the Quarry Stating Area* (Ref. 19)

6.1.5 Borrow Area Development

Development of an off-site Borrow Area is necessary to complete the restoration of the quarry proper. The primary borrow source will be located in the Missouri River floodplain (Figure 6-1). An approximately 25 acre area situated west of the quarry and north of the slough will be developed for this activity. Borrow Area operations, including excavation and transport of soils and reclamation of the area, will be provided in the specifications and drawings for Work Package 513, *Quarry Restoration*.

Residuals Operable Unit, are conducted in a manner that integrates the National Environmental Policy Act (NEPA) values and Comprehensive Environmental Restoration, Compensation, and Liability Act (CERCLA) procedural and documentational requirements. Under the integrated approach followed by the U.S. Department of Energy (DOE) for this site, the CERCLA process is supplemented as appropriate, to incorporate the values of NEPA. A key element of the integrated CERCLA/NEPA process is the determination of the level of environmental analysis appropriate under NEPA. This determination is a function of many factors, including the

complexity of the selected action, the likelihood for significant environmental impacts, and the potential for considerable public interest.

In support of Borrow Area development activities, environmental evaluations pertaining to the following were conducted:

- Cultural resource and historical sites.
- Floodplains and wetlands.
- Threatened and endangered species.

Results of these evaluations specific to the Borrow Area will be presented in subsequent versions of this document.

The quarry is located near the Missouri River in an area that contains a high density of archaeological remains. All major prehistoric periods spanning the last 11,000 years are represented in sites that typically occur along ridges or streams. Early Euro-American sites (e.g., farmsteads and cemeteries), as well as World War II-era sites, are also found in the vicinity of the quarry (Ref. 3).

Several cultural resource and historic site surveys have been conducted in the vicinity of the quarry and the Femme Osage Slough. These surveys include a non-intensive reconnaissance of the Little Femme Osage/River Hills area and intensive Phase I surveys of the quarry proper, quarry water treatment plant, and the quarry haul road (Ref. 3). The surveys documented the presence of numerous prehistoric and historic sites in the area, some of which may be considered eligible for the National Register of Historic Places (see Table 6-1).

Table 6-1 Summary of Cultural Resources in the Vicinity of the Weldon Spring Quarry

SITE NUMBER	SITE FUNCTION	NRHP ELIGIBILITY	NOTES
23SC21	Funerary	Potentially eligible	Avoid or test
23SC80	Village/Campsite	Eligible	Avoid or mitigate
23SC81	Village	Eligible	Avoid or mitigate
23SC83	Campsite	Eligible	Avoid or mitigate
23SC90	Campsite	Not eligible	Lack of integrity
23SC95	Village/Campsite	Potentially eligible	Avoid or test
23SC172	Campsite	Potentially eligible	Avoid or test
23SC173	Campsite	Potentially eligible	· Avoid or test
23SC174	Campsite	Potentially eligible	Avoid or test
23SC176	Campsite	Potentially eligible	Avoid or test
23SC177	Campsite/Farmstead	Potentially eligible	Avoid or test
23SC178	Campsite	Not eligible	Lack of integrity
23SC708	Campsite	Not eligible	Lack of integrity
23SC709	Campsite	Not eligible	Lack of integrity
23SC751	Campsite	Potentially eligible	
23SC754	Campsite	Potentially eligible	Avoid or test Avoid or test

Summary of Cultural Resources in the Vicinity of the Weldon Spring Quarry (Continued)

SITE NUMBER	SITE FUNCTION	NRHP ELIGIBILITY	NOTES -
23SC755	Campsite	Potentially eligible	Avoid or test
23SC756	Farmstead/Guard-post	Potentially eligible	Avoid or test
			7 (VOID OF LEST

Refs. 20, 21, 22, and 23.

Wetland delineation has been performed along the Femme Osage Creek, the Little Femme Osage Creek, and the Femme Osage Slough in accordance with the U.S. Army Corp of Engineers guidelines (Ref. 24). To qualify as a jurisdictional wetland under these guidelines, an area must have hydrophytic vegetation, wetland hydrology, and hydric soil. jurisdictional wetlands are regulated by the U.S. Army Corp of Engineers under Section 404 of the Clean Water Act. These areas have been identified as wetlands on the U.S. Fish and Wildlife Service National Wetland Inventory map (Ref. 25). Table 6-2 summarizes the determination for areas in the vicinity of the quarry.

Table 6 2

Table 6-2 Wetland De	terminations in the Vicinity of the Weldon Spring Quarry
ANCA	DESCRIPTION
Femme Osage Slough	Open waters associated with the slough are classified in the National Wetlands Inventory as unconsolidated bottom, lower perennial riverine wetlands, or permanently flooded wetlands. Potential jurisdictional wetlands are located at the end of the northwest arm, where hydrophytic vegetation occurs along the banks of a shallow expansion of the slough. Jurisdictional wetland determination would require evaluation for hydric soils. Hydrophytic
Little Forms Occasion	veyeldion also occurs along the south bank of the slough (Pef 3)
Little Femme Osage Creek	perennial riverine wetland with an intermittently exposed, unconsolidated bottom. Temporarily flooded palustrine forested wetlands occur sparedically.
	identified as a temporarily flooded, palustrine forested wetland and scrub- shrub wetland (Ref. 3).
Femme Osage Creek	The creek is classified in the National Wetland Inventory as a lower perennial riverine wetland with a permanently flooded unconsolidated bottom. A narrow band along the right side of the channel is identified as a temporarily flooded palustrine emergent wetland (Ref. 3)
Area between the Katy Trail and the Femme Osage Slough	The area is identified in the National Wetland Inventory as a forested, broad-leaved deciduous, palustrine wetland that is temporarily flooded. This area does not exhibit indicators of wetland hydrology or hydric soils and therefore is not considered a jurisdictional wetland (Ref. 26).
Former Vicinity Property 9	A small jurisdictional wetland (0.25 acres) is present in the northeast corner of the area. This wetland is classified as a forested, broad-leaved, deciduous, palustrine wetland that is seasonally flooded (Ref. 26).

The 100-year floodplain of the Missouri River is relatively flat and extends to the base of the escarpment immediately northwest of the Katy Trail. The 100-year floodplain elevation in the vicinity of the quarry is approximately 473 ft above mean sea level (MSL). Located within the floodplain is the Femme Osage Slough. A dike (elevation 470 ft MSL) is located along the Missouri River, bordering the St. Charles County well field and extending northwest along the

Femme Osage Creek and Little Femme Osage Creek, to the Katy Trail. The levee is designed to reduce the frequency of flooding within the St. Charles County well field (Ref. 26)

During the remedial investigation, threatened and endangered species surveys were conducted for four listed species, the bald eagle, loggerhead shrike, Swainson's hawk, and northern harrier, that have been observed in the QROU study area. These surveys were performed to determine if the area was being utilized for feeding, nesting, and/or roosting activities. Also, no designated critical habitats for threatened or endangered species currently exist at or near the quarry (Ref. 27).

The only State or Federal listed species observed during the surveys within the area of the operable unit was the bald eagle. Bald eagles were observed roosting on Howell Island, located across the Missouri River from the quarry, and periodically in trees along the levee of the well field. Many individuals were observed flying along the Missouri River, likely foraging for food. No individuals were observed flying, roosting, or foraging within the well field. A summary of the surveys performed in the area is presented in the *Remedial Investigation* (Ref. 4).

6.2 Work Package 529, Quarry Interceptor Trench System Reclamation

Quarry interceptor trench system reclamation includes demolition of the treatment plant and associated facilities, removal of the interceptor trench system, and possible removal of potentially contaminated residual soils in the quarry proper. The reclamation of the quarry area will include the final grading of the area to near-natural conditions.

6.2.1 Quarry Water Treatment Plant Demolition

As part of the quarry interceptor trench project, the quarry water treatment plant and associated facilities are to be demolished. The major items included in this effort are:

- The quarry water treatment plant building and all piping and equipment related to the treatment plant (contaminated and uncontaminated).
- The equalization basin and all related piping and equipment (contaminated).
- Effluent ponds and all related piping and equipment (uncontaminated).
- Pump station and all related piping and equipment (uncontaminated).
- Quarry water treatment plant effluent pipeline (uncontaminated).
- Pavement (asphalt and concrete) (uncontaminated).

- Aboveground and underground utilities.
- Fencing.

Uncontaminated materials and equipment are to be removed from the quarry area and disposed of at an off-site facility. Contaminated materials and equipment will be disposed of at a licensed disposal facility capable of accepting chemically and radiologically contaminated materials.

6.2.2 Removal of the Interceptor Trench System

As part of the quarry interceptor trench project, the interceptor trench and associated facilities are to be removed or abandoned. The major items included in this effort are:

- Removal of sumps and associated equipment (contaminated).
- Removal of all underground piping (contaminated).
- Removal of all aboveground and underground utilities (uncontaminated).

Materials within the interceptor trench (sumps, utilities, pumps, etc.) will be removed. The granular backfill will be left in-place. Uncontaminated materials and equipment are to be removed from the quarry area and disposed of at an off-site facility. Contaminated materials and equipment will be disposed of at a licensed disposal facility capable of accepting chemically and radiologically contaminated materials.

6.2.3 Removal of Potentially Contaminated Soils

A 1-ft envelope of soil will be removed from below and around the sides of contaminated underground piping during the excavation of pipelines. A 1-ft envelope of soil will also be excavated from the bottom and sides of all contaminated concrete. The following items are considered contaminated:

- Piping between the equalization basin and the quarry water treatment plant.
- Piping between the interceptor trench and the equalization basin.
- Piping between the equalization basin and the leachate sump.
- Concrete floor of the treatment plant process area.

Under best management practices, the areas will be scanned during the excavation activities. Locations exceeding 1.5 time background as measured with a NaI (2X2) meter will be evaluated for additional excavation. It is assumed that if leakage were to have occurred, radiological and chemical contamination would be collocated.

Characterization of the soils beneath and adjacent to the equalization basin will be performed as outlined in the Engineering Characterization Sampling Plan for the Quarry Staging Area (Ref. 18). Samples will be analyzed for Ra-226, Ra-228, Th-230, Th-232, U-238, arsenic, lead, nickel, selenium, nitroaromatic compounds, polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs). This work cannot be performed until completion of the interceptor trench field study.

6.2.4 Final Site Grading

The final grading of the quarry area will tie into the intermediate grading performed during quarry proper restoration. Grading will include the removal of the quarry water treatment plant foundation and basins. Excess soil will be distributed to create a gentle slope from the entrance to the quarry proper to the Little Femme Osage Creek. Slopes will be designed to promote sheet flow. The area will be seeded to prevent erosion and to allow for natural vegetation to become established.

7. CONSTRUCTION ACTIVITIES

Construction activities will be required for the following actions being implemented for the Quarry Residuals Operable Unit (QROU):

- Quarry restoration.
- Interceptor trench construction.
- Interceptor trench reclamation.
- Quarry water treatment plant dismantlement.
- Well installation and abandonment in support of long-term monitoring.

At the Weldon Spring Site Remedial Action Project (WSSRAP), construction tasks are summarized and implemented as work packages. Work packages contain all the specifications, construction drawings, and quality control guidance for the implementation of each project. A safe work plan, bonding, insurance, substance abuse program, subcontractor quality assurance/quality control program, work sequencing forecast, and schedule are required as initial submittals to the Project Management Contractor (PMC) before the subcontractor is given notice to proceed with the work.

The following sections generally discuss the construction activities required for each of these actions. A summary of the construction specifications for each work package will also be included.

7.1 Quarry Reclamation.

Restoration of the quarry area will be performed as two separate work packages. The two packages are:

- WP-513 Quarry Proper Restoration
- WP-529 Quarry Interceptor Trench System Reclamation

7.1.1 Quarry Proper Restoration

Construction activities associated with the restoration of the quarry proper include:

- Development of off-site, contractor-designated borrow sources and haul routes.
- Excavation and transport of borrow materials to the quarry proper.
- Placement and compaction of borrow material to specified grades.

- Removal of transfer station, decontamination pad, fuel stations, and any associated underground piping.
- Removal of asphalt and concrete pavement.
- Removal of fencing.
- Removal of utilities.
- Excavation and transport of contaminated soils and materials.
- Installation of permanent surface water control measures.

The following is an initial list of specifications for Work Package 513, Quarry Restoration:

01010	Summary of Work
01025	Measurement and Payment
01300	Submittals
01400	Quality Assurance and Quality Control
01420	Hold and Witness Points
01503	Temporary Utilities
01510	Temporary Facilities
01560	Emission Controls
01570	Traffic Regulations
01736	Haul Road Operations
02005	Surveying Services
02055	Facility Dismantlement/Demolition, Soil Removal and
	Transportation
02200	Earthwork
02270	Erosion Control
02485	Seeding
03660	Quarry Highwall / Floor Stabilization
15220	Piping

7.1.2 Quarry Interceptor Trench System Reclamation

Construction activities associated with the reclamation of the quarry interceptor trench includes demolition of the quarry water treatment plant and removal of the interceptor trench system. Tasks associated with the reclamation project include:

55

- Removal of equalization basin, effluent ponds (2), and any associated liners and piping
- Dismantlement of the water treatment system.
- Demolition and removal of the water treatment building.
- Removal of pumps, piping, and structures associated with the pilot-scale interceptor trench.
- Excavation and transport of contaminated soils and materials.
- Plugging of the quarry water treatment plant effluent pipeline.
- Demolition and removal of the effluent pipeline outfall structure.
- Removal of asphalt and concrete pavement.
- Removal of fencing.
- Excavation and transport of borrow materials to the quarry proper to attain final grades.
- Placement and compact of borrow material to specified grades.
- Final grading of the quarry water treatment plant and interceptor trench areas.
- Installation of permanent surface water control measures.

The following is an initial list of specifications for Work Package 529, Quarry Water Treatment Plant Dismantlement:

01010	Summary of Work
01025	Measurement and Payment
01300	Submittals
01400	Quality Assurance and Quality Control
01420	Hold and Witness Points
01503	Temporary Facilities
01510	Temporary Utilities
01560	Emission Controls
01570	Traffic Regulations

01736	Haul Road Operations
02005	Surveying Services
02055	Facility Dismantlement/Demolition, Soil Removal and
	Transportation
02200	Earthwork
02270	Erosion Control
02485	Seeding

7.2 Quarry Interceptor Trench System

Construction activities associated with the construction of the quarry interceptor trench system include installation of the 550-ft. interceptor trench and connection to the quarry water treatment plant. Specific tasks include:

- Excavation of the interceptor trench.
- Placement of granular backfill
- Placement of piping, pumps, and vaults.
- Connection to the quarry water treatment plant.
- Installation of observation wells (see Section 8.3).
- Re-grading of the construction area.

The following is an initial list of specifications for Work Package 515, Quarry Interceptor Trench System:

Summary of Work
Measurement and Payment
Submittals
Quality Assurance and Quality Control
Hold and Witness Points
Temporary Utilities and Temporary Construction
Emission Controls
Traffic Regulations and Haul Road Operations
Surveying Services
Earthwork
Site Grading
Erosion Control
Contaminated Water Management and Transporation
Seeding
Filter Material
Pumps
Mechanical General Provisions

Process and Utility Piping
Valves
Mechanical System Startup and Commissioning
Basic Electrical Requirements
Electrical Testing and Installation Check
Raceways
Wire and Cable
Boxes
Cabinets and Enclosures
Electrical Identifications
Disconnect Switches
Grounding
Dry Type Transformers
Panelboards
Instrumentation

7.3 Monitoring Well Installation and Abandonment

Installation of new monitoring wells and observation wells and abandonment of existing wells, which will not be utilized for monitoring will be performed in support of the long-term monitoring program. The following is a list of task performed in support of this effort.

- Soil augering
- Soil sampling.
- Rock coring.
- Rock reaming.
- Packer testing.
- Installation of well screen and casing.
- Installing of filter pack and annular seal.
- Installation of protective casing and bollards.
- Over-drilling of well screen and casing.
- Reaming of well materials
- Grouting of boreholes.

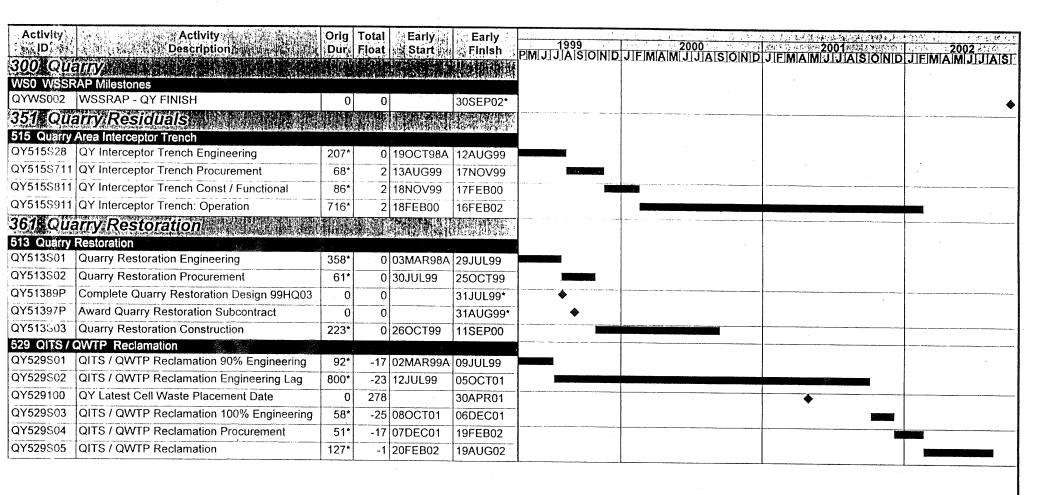
Monitoring well installation and abandonment will be performed under Work Package 487, *Monitoring Well Installation and Abandonment*. The following is a list of specifications associated with this work package:

01400	Quality Assurance and Quality Control
	Well Installation and Abandonment

8. PROJECT SCHEDULE

The schedule (Figure 8-1) associated with the design, procurement, and construction of the following activities is provided in this section:

- Quarry Proper Restoration design and construction.
- Quarry Interceptor Trench System design, construction, and operation.
- Quarry Reclamation design and construction.



Project Start 02JUN97
Project Start 010CT02
Project Flinish 010CT02
Date Date 09APR99
Run Date 07APR99
Run Date 07APR99
Prifmawera Systems, Inc.

WSRP WSQY

QUARRY RESIDUALS OPERABLE UNIT
PROJECT SCHEDULE

FIGURE 8-1

9. SUMMARY OF PROJECT COSTS

Costs associated with the design and construction of the selected remedy are provided in the following sections. Costs are provided for the following components:

- Quarry Proper Restoration design and construction.
- Quarry Interceptor Trench System design, construction, and operation.
- Quarry Reclamation design and construction.
- <u>Long-term Monitoring</u> construction, field support, analysis.
- Northeast Corner Characterization field support and analysis.
- <u>Interceptor Trench Field Study</u> field support and analysis.
- <u>Hydrogeologic Field Study</u> field support and analysis.

9.1 Quarry Reclamation

Table 9-1 summarizes the costs associated with design and construction for restoration of the quarry proper and reclamation of the quarry interceptor trench system, which includes demolition of the quarry water treatment plant and final site grading.

Table 9-1 Summary of Costs for Quarry Reclamation

PROJECT	TASK	COST
Quarry Proper Restoration	Design	\$ 483,000
	Construction	\$ 4,280,407
Quarry Interceptor Trench System Reclamation	Design ⁽¹⁾	\$ 50,000
	Construction	\$ 1,351,602

Note: 1 90% of the design was performed under Quarry Proper Restoration

9.2 Quarry interceptor Trench System

Table 9-2 summarizes the costs associated with design and construction for quarry interceptor trench system. Also included is the start-up of the system and operation for a 2-year period.

Table 9-2 Summary of Costs for the Quarry Interceptor Trench System

PROJECT	TASK	COST
Quarry Interceptor Trench System and Start-Up	Design	\$ 156,000
	Construction	\$ 442,018
Quarry Interceptor Trench System Operations	Design ⁽¹⁾	\$ 25,000
	Operation	\$ 1 103 132

Note: 1 80% of the design was performed under Quarry Interceptor Trench System and Start-Up

9.3 Long-Term Monitoring

Table 9-3 summarizes the costs associated with installation of new monitoring wells and the abandonment of those wells that are not incorporated into the monitoring network. Also included are costs associated with sample collection and analysis for the next 5 years.

Table 9-3 Summary of Costs for Long-Term Monitoring

PROJECT	COSTS	
Monitoring well installation (1 well)	\$21,120	
Monitoring well abandonment (21 wells)	\$146,809	
Analytical Services (1)	\$113,850	

Note: 1 See Section 2 of this report for collection frequency and analytical parameters

9.4 Field Studies

Table 9-4 summarizes the costs associated with the sample collection and analysis necessary for the performance of the interceptor trench field study and the hydrogeological field study.

PROJECT	TASK	COST
Interceptor Trench Field Study	Drilling/Well installation services	
	Analytical services	\$49,749
Hydrogeologic/Geochemical		\$168,360
Characterization Field Study	Drilling services	\$33,741
5 Maradenization Field Olday	Analytical services	\$17,940

10. QUALITY ASSURANCE PROGRAM

The Project Management Contract (PMC), as obligated by the Department of Energy (DOE) Order 414.1, Quality Assurance has developed the Project Management Contractor Quality Assurance Program (QAP) (Ref.28). This plan describes not only the overall quality assurance program implemented at the Weldon Spring Site Remedial Action Project (WSSRAP), but also includes requirements for personnel training, quality improvement, documents and records, work processes, design, procurement, inspection and acceptance testing, and a routine assessment program.

10.1 Purpose

The PMC develops, implements, and maintains a written QAP. The QAP describes the organizational structure, functional responsibilities, levels of authority, and interfaces for those managing, achieving, and assessing adequacies of work. The QAP describes the management system, including planning, scheduling, and cost control considerations.

The QAP satisfies the requirements of:

- Morrison Knudsen Corporation Management.
- Jacobs Engineering Group, Inc. Management.
- DOE Order 414.1, Quality Assurance.
- 10 CFR 830.120, Quality Assurance.

American Society of Mechanical Engineers (ASME) NQA-1, U.S. Environmental Protection Agency (EPA) documents, and the American National Standards Institute/American Society for Quality (ANSI/ASQ) - E4 were also used as guidance documents with the applicable sections being incorporated, as appropriate.

10.2 Description

The PMC QAP reflects the mission, policies, and objectives for the WSSRAP. The program is a broad-based program that applies to every aspect and employee at the WSSRAP.

The QAP identifies mechanisms necessary for the planning, implementation, and assessment of quality-affecting activities. These mechanisms are applied using a graded approach, which takes into account that not all items, processes, or services have the same impact on the quality, safety, or reliability of an activity. Mechanisms outlined in the QAP are:

- Personnel indoctrination and training.
- Quality improvement.

- Documents and records
- Work processes.
- Design.
- Procurement.
- Inspection and acceptance testing.
- Management assessment.
- Independent assessment.

10.3 Implementation

The PMC Project Quality Manager and his designees conduct independent assessment of the performance of the project in relation to the requirements of the QAP and departmental standard operating procedures and instructions. These assessments area performed in accordance with the QAP.

The QAP, together with implementing procedures and instruction, form an integrated management that ensures compliance with specified standards, personnel safety, and protection of the environment. The significant features of the QAP are:

- Quality verification and overview of activities that demonstrate the completeness and appropriateness of achieved quality
- Assurance that activities are performed to specified requirements.
- Assurance that structures, systems, and components will perform as intended.

Quality is achieved by ensuring that managers at all level are responsible and accountable for achieving and improving upon quality. All PMC personnel are responsible for the quality of the work at the WSSRAP.

The quality assurance/quality control (QA/QC) requirements for specific task performed under the scope of this work plant will be addressed future documents. The QA/QC requirements for construction activities will be presented in the technical specifications for the appropriate work packages. The QA/QC requirements for sampling and characterization activities will be address in the appropriate sampling or monitoring plans.

11. CONTINGENCY PLAN

11.1 Purpose

The Project Management Contractor (PMC) has prepared the *Emergency Plan* (Ref. 29), which establishes the planning, preparedness, and response concepts for operational emergencies and other emergencies at the Weldon Spring Site Remedial Action Project (WSSRAP). The emergency management response measures established by the *Emergency Plan* are intended to afford protection for the health and safety of on-site personnel and the public, limit damage to facilities and equipment, minimize impact to on-site operations, and limit adverse impacts on the environment. The plan is implemented whenever an emergency situation is declared or conditions exist that constitute, or could result in, an operational emergency at the WSSRAP. Appropriate parts of the plan may be implemented by a responsible authority for emergencies that do not reach the severity of an Operation Emergency, but require a structured response pursuant to environmental or health and safety regulations or sound management practices. The plan also outlines the interfaces and coordination with off-site private organizations, and Federal, State, and local government agencies with roles in emergency response.

11.2 Description

The *Emergency Plan* is designed to address planning for all categories of emergencies arising at or as a result of, operations conducted by the WSSRAP that could affect people, property, or the environment. The scope and extent of the planning is commensurate with the hazards present at the WSSRAP.

The *Emergency Plan* addresses specific categories of events and defines basic response actions to be followed for each type of incident. Topics discussed are:

- WSSRAP emergency response organization.
- Off-site response interfaces.
- Emergency event classification.
- Notification and communication.
- Hazard assessment process.
- Protective actions.
- Medical support.
- Reentry and recovery.
- Public Information.
- Emergency facilities and equipment.
- Training.
- Drills and exercises.
- Emergency management program administration.

This plan implements the requirements of 40 CFR 264 and 10 CSR 25-7.264 for a RCRA Contingency Plan. This plan also incorporates the requirements of 40 CFR 112 for a Spill Prevention Control and Countermeasures Plan, and 29 CFR 1910.120 and 29 CFR 1926.65 for an Emergency Response Plan. Outside agency hazardous material incident notification guidance is contained in the WSSRAP Reportable Release Notification Guide (Ref. 30).

11.3 Implementation

It is the policy of the U.S. Department of Energy (DOE) and the WSSRAP management to conduct operations in a responsible manner so as to be protective of human health and the environment. The primary focus of site management is the prevention of accidents, emergency situations, and other incidents, which could adversely affect on-site personnel, the public, property, or the environment. These objectives are attained through the implementation of effective planning and preparedness for emergencies during the initial stages of site activities. Also, the use of protective actions and training maintains an awareness of potential emergencies and the appropriate responses required for prevention or mitigation of problems that could occur.

Specific provisions for responding to emergencies that are unique to individual tasks in the remedial action activities are incorporated into job-specific health and safety plans, safe work plans, and/or task specific safety assessments. For each activity, the health and safety plan is the primary working document that governs initial safety, health, and emergency response requirements. The health and safety plan also provide subcontractors with the process for identifying potential emergency conditions and notifying the appropriate WSSRAP contact.

12. POST-ROD DOCUMENTATION

This section outlines the primary and secondary documents that will be prepared to support the design and implementation of the selected remedy for the Quarry Residuals Operable Unit (QROU). Primary documents include those documents that are major, discrete portions of the remedial design and remedial action activities. Secondary documents are typically feeder documents to a primary document. A secondary document may be finalized in the primary document that it supports or it may be issued as a stand-alone document. The schedule for the documents being prepared in support of the design and construction for this operable unit will be included and updated in the quarterly reports prepared in accordance with the Federal Facilities Agreement (Ref. 2).

12.1 Primary Documents

12.1.1 Final Design Submittals

The final design submittal includes drawings and specifications that are ready for bid advertisement. Each submittal will contain:

- Design analysis.
- Final construction drawings.
- Final construction specifications.
- Construction quality control standards.
- Cost estimate

Final design submittals will be issued for the following components:

- WP-513, Quarry Interceptor Trench System.
- WP-515, Quarry Restoration.
- WP-529, Quarry Interceptor Trench System Dismantlement.

12.1.2 Hydrogeologic Characterization Sampling Plan in Support of the QROU Field Studies

This plan (Ref. 16) includes information concerning the scope and methodology for collection of hydrologic and geologic characterization data from the area north of the Femme Osage Slough. Data collection was performed during January and February 1999.

12.1.3 Geochemical Characterization Sampling Plan in Support of the QROU Field Studies

This plan will include information concerning the scope and methodology for collection of geochemical characterization data from the area north of the Femme Osage Slough.

12.1.4 Sampling Plan for Radiological Characterization of the Northeast Slope Area of the Weldon Spring Quarry

This plan will include information concerning the scope and methodology for collection of data to delineate the extent of radiological contamination in the soils in the northeast slope area of the quarry

12.1.5 Sampling Plan for Radiological Characterization of the Ditch Area of the Weldon Spring Quarry

This plan will include information concerning the scope and methodology for collection of data to delineate the extent of radiological contamination in the soils in the ditch area near the transfer station at the quarry.

12.1.6 Reevaluation of the Risk for the Northeast Slope Area of the QROU

This document will present the re-evaluation of baseline risk based on the data presented in the Completion Report of the Radiological Characterization of the Northeast Slope Area at the Weldon Spring Quarry. An interpretation of the data and recommendations on possible soil removal will be included.

12.1.7 Evaluation of the Performance of the Interceptor Trench Field Study

This document will summarize the data collected during the field study and present the comparison to the modeled performance of the trench. Conclusions regarding the benefits of uranium removal through groundwater extraction from the area north of the slough will be made.

12.1.8 Operations and Maintenance Plan

The preparation of an *Operations and Maintenance Plan* for each operable unit continuing actions, such as monitoring, is outlined in the *Federal Facilities Agreement* (Ref. 2). Section 2 of this *Plan* will fulfill the requirements of the *Operations and Maintenance Plan*.

12.1.9 Contingency Plan

The Weldon Spring Site's *Emergency Preparedness Plan* (Ref. 29) will be used to fulfill the requirement for the preparation of a contingency plan for this work being performed for this operable unit.

12.1.10 Remedial Action Report

The remedial action report documents the completion of an operable unit. The report indicates that the operable unit has met the objectives of the *Record of Decision* (Ref. 1) and provides summary information for subsequent inclusion in the preliminary and final closeout reports.

12.2 Secondary Documents

12.2.1 Preliminary Design Submittals

The preliminary design submittal consists of the 60% design effort for each component outlined in Section 12.1.1 of this plan.

- 60% construction drawings.
- 60% construction specifications.
- Preliminary construction quality control standards.

12.2.2 Completion Report for Hydrogeological Field Studies in Support of the QROU

This completion report will summarize all field activities and data results obtained from the characterization field studies. This data will be incorporated into the Evaluation of the Performance of the Interceptor Trench Field Study.

12.2.3 Completion Report for Radiological Characterization of the Northeast Slope Area at the Weldon Spring Quarry

This completion report will summarize all field activities and data results obtained from the characterization effort. Data from this completion report will be incorporated into the Reevaluation of the Risk for the Northeast Slope Area of the QROU.

12.2.4 Completion Report for Radiological Characterization of the Ditch Area at the Weldon Spring Quarry

This completion report will summarize all field activities and data results obtained from the characterization effort. Data from this completion report will be used to determine the excavation limits for contaminated soils and will be documented in the construction documents and drawings for Work Package 513, *Quarry Restoration*.

12.2.5 Well Field Contingency Plan

This *Plan* will outline the contingencies to be considered if long-term monitoring indicates an impact to the potable water supply from the St. Charles County well field. Emphasis will be placed on information necessary to support the development of a replacement well field and design criteria for design and construction of this well field, if necessary.

12.2.6 Construction Progress Reports

The Federal Facilities Agreement quarterly reports will fulfill the requirements for the Construction Progress Report for this operable unit. Copies of daily, weekly, and monthly reports submitted by the subcontractor, as well as quality control inspections, are maintained at the site. These documents can be made available, upon request, to the regulators for inspection.

13. REFERENCES

- 1. Argonne National Laboratory. Record of Decision for Remedial Action for the Quarry Residuals Operable Unit at the Weldon Spring Site, Weldon Spring, Missouri. DOE/OR/21548-725. Prepared for the U.S. Department of Energy, Oak Ridge Operations Office. St. Charles, MO. September 1998.
- 2. U.S. Environmental Protection Agency. First Amended Federal Facilities Agreement, Docket No. CERCLA-VII-85-F-0057. Prepared for U.S. Department of Energy, Weldon Spring Site. St. Charles, MO. January 28, 1992.
- 3. Argonne National Laboratory. Work Plan for the Remedial Investigation/Feasibility Study-Environmental Assessment for the Quarry Residuals Operable Unit at the Weldon Spring Site. DOE/OR/21548-243. Prepared for the U.S. Department of Energy, Weldon Spring Site Remedial Action Project by the Environmental Assessment Division. St. Charles, MO. January 1994.
- 4. MK-Ferguson Company and Jacobs Engineering Group. Remedial Investigation for the Quarry Residuals Operable Unit of the Weldon Spring Site, Weldon Spring Missouri. Rev. 2. Final. DOE/OR/21548-587. Prepared for the U.S. Department of Energy, Oak Ridge Operations Office. St. Charles, MO. February 1998.
- 5. Argonne National Laboratory. Baseline Risk Assessment for the Quarry Residuals Operable Unit of the Weldon Spring Site, Weldon Spring, Missouri. DOE/OR/21548-594. Prepared by the Environmental Assessment Division for the U.S. Department of Energy, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri. July 1997.
- 6. Argonne National Laboratory, Environmental Assessment Division. Feasibility Study for Remedial Action for the Quarry Residuals Operable Unit at the Weldon Spring Site, Weldon Spring, Missouri. DOE/OR/21548-595. Prepared for the U.S. Department of Energy, Oak Ridge Operations Office. St. Charles, MO. March 1998.
- 7. Argonne National Laboratory. Proposed Plan for Remedial Action at the Quarry Residuals Operable Unit of the Weldon Spring Site. DOE/OR/21548-724. Prepared for the U.S. Department of Energy, Oak Ridge Operations Office. St. Charles, MO. March 1998.
- 8. U.S. Department of Energy. Record of Decision for Remedial Action at the Chemical Plant Area of the Weldon Spring Site. Rev. 0. DOE/OR/21548-376. Oak Ridge Field Office. St. Charles, MO. September 1993.

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- 10. ASER (draft) Doc. 773
- 11. MK-Ferguson Company and Jacobs Engineering Group. Weldon Spring Site Environmental Report for Calendar Year 1997. Rev. 0. DOE/OR/21548-730. Prepared for the U.S. Department of Energy, Oak Ridge Operations Office. St. Charles, MO. August 1998.
- 12. Ground-Water Flow and Ground- and Surface-Water Interaction at the Weldon Spring Quarry, St. Charles County, Missouri (USGS Doc 96-4279)
- MK-Ferguson Company and Jacobs Engineering Group. Sample Management Guide. Rev.
 DOE/OR/21548-499. Prepared for the U.S. Department of Energy, Oak Ridge Operations Office. St. Charles, MO. August 1997.
- 14. Stewardship Plan (Draft) Doc. 771.
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 6. Prepared for the U.S. Department of Energy, Oak Ridge Operations Office. February 1999.
- 16. MK-Ferguson Company and Jacobs Engineering Group. *Hydrogeologic Characterization Sampling Plan in Support of the QROU Field Studies*. Rev. 0. DOE/OR/21548-764. Prepared for the U.S. Department of Energy, Oak Ridge Operations Office. St. Charles, MO. November 1998.
- 17. Design Criteria for WP-508, Architect/Engineer Services VI, Task 4, Rev 0
- 18. MK-Ferguson Company and Jacobs Engineering Group. Engineering Characterization Sampling Plan for the Quarry Staging Area. Rev. 0. DOE/OR/21548-753. Prepared for the U.S. Department of Energy, Oak Ridge Operations Office. St. Charles, MO. October 1998.
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- 22. A Phase I Survey and Evaluation of the Weldon Spring Quarry Potable Waterline Project And Phase II Testing of Archaeological Sites 23SC80, 23SC81, and 23SC83, St. Charles County, Missouri
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- 34. U.S. Environmental Protection Agency. Statement of Work for Inorganic Analysis Multi-Media Multi-Concentration, SOW No. 744. USEPA Contract Laboratory Program. February 1989 and June 1989.
- 35. Hydrogeological Characterization Sampling Plan in Support of the QROU Field Studies

APPENDIX A Groundwater Modeling Information for the Quarry Area

A. GROUNDWATER MODELING INFORMATION FOR THE QUARRY AREA

Groundwater modeling has been performed to assess the hydrogeologic system of the well field area in order to predict contaminant movement and potential impacts to the well field. Calculations and models are tools used to assist in decision making. They utilize known and estimated values of aquifer dimensions and properties, total water budget, and contaminant characteristics within the study area.

A.1 Radius of Influence Calculation

Using methods described by the U.S. Environmental Protection Agency to estimate the radius of influence for a pumping well, the effects of pumping from the quarry pond (dewatering) were calculated (Ref. 9). This calculation was performed to assess monitoring locations during bulk waste removal activities. Using a composite hydraulic conductivity of 4.7×10^{-4} cm/s, a saturated thickness of 100 ft, a head of 20 ft, a pumping rate of 80 gal/min, and a pumping well radius of 25 ft, the resulting radius of influence was determined to be 344 ft. This result suggests that the radius of influence will not extend into the alluvium north of the slough. Results from static water level measurements in bedrock monitoring wells located around the quarry pond support the conclusion that the radius of influence is small (Ref. 31). Based on this information, pumping from within the quarry would not capture the uranium plume in the alluvial materials and bedrock south of the quarry.

A.2 Analytical Modeling

The effects of contaminant transport in the quarry area were evaluated as a result of (1) a disturbed contaminant source due to remedial action and (2) the influence of the Femme Osage Slough as a concentration sink (Ref. 32 and 33). These efforts utilized available site-specific data and conservative assumptions to evaluated contaminant behavior in a dimensionless form. In general, the analyses found that in both of these cases, contaminant concentrations in groundwater between the quarry and the slough should generally decrease as a result of quarry pond dewatering.

A.3 Numerical Modeling

A numerical model was completed in support of the remedial investigation to assess migration pathways of uranium contaminated groundwater originating from north of the slough (Ref. 4). Also, estimated were made of uranium concentrations in groundwater between the slough and the well field and concentrations of the discharge from production wells for a worse-case scenario.

The study area (Figure A-1) includes the wedge shaped around bounded by the Katy Trail, the Missouri River, and an arbitrary boundary a few miles south of the Femme Osage

Creek. The location of the Katy Trail was used to approximate the contact between the alluvium and the bedrock, where the groundwater flows from the bedrock across the contact into the alluvium. The bottom of the model was the underlying bedrock surface (Plattin Limestone).

The following assumptions form the basis of the model scenario presented in the Remedial Investigation:

- Average, steady-state hydrologic conditions exist.
- Contaminant transport will be based on the simulated steady-state hydrologic conditions.
- The source of uranium contamination to the well field area originates from north of the slough and is uniform and continuous.
- The average concentration of the plume along a cross-section perpendicular to the flow path is 2,800 pCi/l.
- All chemical or hydraulic barriers to migration of the uranium plume toward the well field do not exist.

A total groundwater pumping rate of 10.5 million gallons per day (gpd) was divided evenly among the eight active production wells. Although at times fewer than eight wells may be pumping simultaneously, the pumping is distributed evenly over all the wells over the length of the simulation.

Approximately 14,200-gpd influx was assigned to the section of the boundary representing the discharge from the contaminated plume. This value was calculated using a flow net analysis of the potentiometric surface for typical groundwater conditions at the quarry (Ref. 4). The uranium plume was modeled as a constant recharge at the model boundary with a fixed concentration of 2,800 pCi/l (4,000 μ g/l). This value is the maximum average concentration along a cross-section of the plume (Ref. 4). This condition establish an unlimited source of uranium to the groundwater at a constant concentration south of the slough and represents an extreme case, which is not expected to occur due to the removal of the bulk wastes from the quarry.

Based on a steady-state model, the contaminant plume would primarily be captured by production well PW-8, with minor capture occurring in PW-9. The base model did not incorporate retardation (redox reactions and adsorption) or dispersion of the contaminant as it migrates from the area north of the slough. Simulations using conservative values for these

conditions indicate that retardation has the greater influence on the length of contaminant travel times.

The model presented in the *Remedial Investigation* (Ref. 4) was expanded to include retardation of the contaminant plume. Site-specific data regarding distribution coefficients (Kd) for uranium and other aquifer characteristic parameters were used. This version of the model was used to estimate contaminant concentrations in monitoring wells and production wells along the flow path based on the same hypothetical migration scenario presented in the *Remedial Investigation*.

Distribution coefficients were determined using soil samples for the alluvial materials both north and south of the slough. These values ranged form 1.2 ml/g to 38 ml/g, with an average value of 30 ml/g. A value of 1.2 ml/g was used in the model for conservatism and it would also be expected that the coarse-grained alluvium would have a lower Kd value.

The results indicate it would be approximately 5 years to 8 years before contamination would be observed in a monitoring well directly south of the slough (MW-1018). It would be 10 years to 15 years before impact would be observed in a RMW-series well (RMW-4). Levels greater than 8 pCi/l above background levels were not predicted in a production well within the 100-year simulation period. This scenario did not take into account any precipitation of dissolved uranium from the groundwater (redox reaction) or dilution along the flow path in the well field.

INTER-OFFICE CORRESPONDENCE

October 8, 1992

Jeff Carman TO:

Shawna Murray (M

ROM:

RADIUS OF INFLUENCE CALCULATION FOR THE WSQ SUBJECT:

The radius of influence calculation presented below was performed to estimate 1) the location of monitoring wells for monitoring the water levels and water quality and 2) the area potentially effected by the dewatering of the WSQ pond.

The radius of influence is the horizontal distanced from the center of a well to the limit of the cone of depression (Driscoll, 1986). The radius of influence can be calculated using equation 1 (EPA 1985). This calculation is modified from the Jacob method and can be used for unconfined aquifers providing the drawdown (H-h) is not a large percentage of the saturated thickness of the aquifer.

$$\frac{Q}{H^2 - h_w^2} = \pi \frac{k}{\ln \frac{r_o}{r_w}} \tag{1}$$

simplifying

$$\ln r_o = \frac{\pi k H^2 - h_w^2}{Q} + \ln r_w$$

where:

r_o = radius of influence (ft)

k = hydraulic conductivity (gpd/ft^2)

H = total head (ft)

h, = head in well (ft)

Q = pumping rate (gpm)

r = well radius (ft)

Page 2 RADIUS OF INFLUENCE CALCULATION FOR THE WSQ

Assumptions include:

- Unconfined aquifer (the quarry pond itself acting as large diameter well).
- Aquifer at equilibrium conditions (for simplicity and data unavailable at this time to conduct calculations under non-equilibrium conditions).
- Aquifer is homogeneous and isotropic (for applicability of Darcy's Law).
- No recharge to aquifer.

The hydraulic conductivity of the bedrock aquifer is assumed to be 10 gpd/ft^2 (BGA 1984). The quarry pond is in the Decorah Group which is primarily horizontally fractured. Total head for the bedrock aquifer is assumed to be 100 ft due to the apparent connection between the Decorah Group and the Plattin Limestone. This connection has not been confirmed, but is evidenced by the water level data (the Decorah Group may be considered a leaking confining unit connecting the Kimmswick Limestone (recharge zone) and the Plattin Limestone). Further study of the connection between these units will be conducted under the scope of the quarry residuals separate operable unit. The head in the well is approximately 20 ft with a well radius of 25 ft because the sump depth is assumed to be 20 - 25 ft and the sump radius is approximately 25 ft. The design pumping rate is 80 gpm (ANL 1989).

Inputting the parameters described above the radius of influence due to the pumping of the quarry pond is 344 ft. This distance is sightly greater than the distance measured between the quarry pond and the Femme Osage Slough (measured in the primary direction of groundwater flow). For purposes of the location of upgradient (background) monitoring wells the radius of influence was assumed to be uniform; however this most likely will not be the case (the flow lines this most likely will steepen) therfore the distance upgradient of the quarry will steepen) therfore the distance used was between 350 to 400 ft from the quarry pond.

The calculations will be refined as more data becomes available.

Page 3 RADIUS OF INFLUENCE CALCULATION FOR THE WSQ

References:

ANL 1989, Engineering Evaluation/Cost Analysis for the Proposed Management of Contaminated Water in the Weldon Spring Quarry DOE/OR/21548-039

Driscoll, F.G. 1986 Groundwater and Wells Johnson Division, St. Paul, Missnesota 1986

EPA 1985 Leachate Plume Management EPA/540/2-85/004

Eerkely Geosciences 1984 Cahracterization and Assessment for the Weldon Spring Quarry Low Level Radioactive Waste Storage Site DOE/OR-853

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Attachments

Distribution:

R. Ferguson EC 3.10

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SUBJECT Redius of Influence. From quemy sums SHEET 1 071 DATE 9-28-92 BYR. Ference CARC. S. MULKEY JOB NO. WSQ-BUST

Assumptions:

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Vo= radius of influence (A) h= hydraulic conductivity (gpd/12) H = sourced whichess (7) hw=hedinuell (A) Q= purping rate (gpm) Vw= well radius (A)

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In vo = (10 = 10 = 100 = 200 = 10 25 =

In vo = 5.84 A ro = 341

References:

- (1) Leachate Aume Management EAA/500/2-85/004 Nov. 1985
- (2) P. Randial luxstitutions for Quarry Bulk Wester FIE/OR/Z1548-066 121
- (3) Engineering Evaluation | Cost Analysis Forthe Proposed Management of Contaminate Water in the Wolfen Spring Quarry DCE/CR/21595-039 1/89

WELDON SPRING SITE REMEDIAL ACTION PROJECT

WSSRAP QUARRY RESIDUALS OSE

Migration of Uranium-Contaminated Groundwater in the St. Charles County Well Field Task 887

Technical Memorandum No. 3840TM-3030-00

December 1997

Rev. 0

Prepared By

MK-Environmental Services 720 Park Boulevard Boise, ID 83729

for

MK-Ferguson Group 7295 Highway 94 South St. Charles, MO 63304

Migration of Uranium-Contaminated Groundwater in the St. Charles County Well Field Task 887

Technical Memorandum No. 3840TM-3030-00

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1.0 PURPOSE AND SCOPE

The purpose of this study is to incorporate recent estimates of distribution coefficients (Kd's) into the groundwater flow and transport model presented in the Remedial Investigation (DOE, 1997) and use the updated model to estimate future contaminant concentrations in the St. Charles County Well Field (Figure 1).

The following scope of work will be completed using the updated model:

- 1. Estimate the sampling frequency required to monitor future movement of uranium contamination for wells MW-1018 and RMW-4 located between the Femme Osage Slough and the Well Field production wells.
- 2. Determine if any additional monitoring wells may be necessary to monitor potential contaminant migration from the area north of the Femme Osage Slough into the Well Field.
- 3. Construct a graph showing concentration vs time for wells MW-1018 and RMW-4 and the production well PW-8. The graphs should show when concentrations in the monitoring wells reach 300 pCi/l (441 μ g/l) and when production well PW-8 reaches 14 pCi/l (21 μ g/l). (13.6 pCi = 20 μ g U)

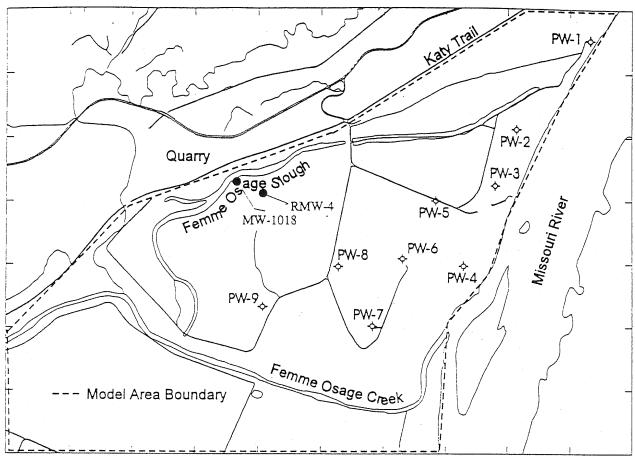


Figure 1 Study Area

2.0 INTRODUCTION

The groundwater between the quarry and Femme Osage Slough is contaminated with uranium at levels as high as 5000 pCi/liter. The contamination appears to be isolated to the area north of the slough, between the slough and the quarry, and has not migrated south of the slough. The lack of contamination south of the slough may be a result of the reduction of uranium in an area of low oxidation potential in the vicinity of the slough. Adsorption, dilution, or hydraulic containment due to seepage flow from the slough may also act to contain the contamination north of the slough.

The St. Charles County well field is located in the area between the slough and the Missouri River. Eight wells pump about 10.5 mgd from the deep alluvial aquifer. Although no uranium contamination has been found in the well field, there is concern that the pumping will eventually draw contaminated water into the well field south of the slough

2.1 Assumptions

The following assumptions form the basis for the computer model used in this report:

- Whatever chemical or hydraulic barriers to migration of the uranium plume toward the well field that might exist have been removed.
- Seepage from the slough does not prevent the migration of contaminants from the area north of the slough.
- Average, steady state hydrologic conditions will be simulated.
- Chemical transport will be based on the simulated steady state hydrologic conditions.
- The source of uranium contamination is fixed and unlimited and located in the area of the uranium plume north of the slough.

3.0 DESCRIPTION OF THE COMPUTER PROGRAM

A computer groundwater flow model was used in an earlier study (MKES, 1997) to estimate the uranium concentration at pumping wells in the well field and determine the flow path from the area of uranium contaminated groundwater north of the slough assuming that the contamination has broke through whatever barrier to migration there might be. The same model was used in this study to estimate the affects of the new distribution coefficients.

MODFLOW was used to determine the steady state water level conditions. MT3D was used to estimate the concentration of uranium contamination in the groundwater under steady state hydrologic conditions determined by MODFLOW. MT3D uses the method of characteristics (MOC) to solve the transport equations. The MOC places particles in the hydrologic system and determines their concentration as it follows the particles along the flow paths.

The computer model MT3D simulates dispersion and retardation. Dispersion refers to the process whereby a plume will spread out in a longitudinal direction (along the direction of groundwater flow), transversely (perpendicular to groundwater flow), and vertically downwards due to mechanical mixing in the aquifer and chemical diffusion. Selection of dispersivity values is a difficult process, given the impracticability of measuring dispersion in the field. However, simple estimation techniques based on the length of the plume or distance to the measurement point ("scale") are available from a compilation of field test data. Note that researchers indicate that dispersivity values can range over 2-3 orders of magnitude for a given value of plume length or distance to measurement point (Gelhar et al., 1992). A typical formula for dispersivity is 0.1 x plume length (Pickens and Grisak, 1981).

No site specific dispersion data is available. The plume length in this study may vary from 0 ft to 800 ft, depending on the other model parameters assumed and the time frame. A uniform dispersivity of 30 ft was used assuming an average plume length of 300 ft.

Retardation is the rate at which dissolved contaminants moving through an aquifer can be reduced by sorption of contaminants to the solid aquifer matrix. The degree of retardation depends on both aquifer and constituent properties. The retardation factor is the ratio of the groundwater seepage velocity to the rate that organic chemicals migrate in the groundwater. A retardation value of 2 indicates that if the groundwater seepage velocity is 100 ft/yr, then the organic chemicals

migrate at approximately 50 ft/yr. Retardation is assumed to be a reversible process described by a linear adsorption isotherm:

$$R=1+\frac{\rho_b}{\theta}K_d$$

4.0 MODEL DESCRIPTION

The study area is shown in Figure 1. The modeled area includes the wedge shaped area bounded by the Katy Trail north of the slough, the Missouri River on the east, and an arbitrary boundary a few miles south of Osage Creek. The Katy Trail approximates the contact between the Missouri River alluvium and the bedrock aquifer. Groundwater apparently flows from the bedrock across the contact into the alluvium.

The alluvial aquifer was modeled as two layers: the upper layer representing the fine grained silts and sands, the lower layer representing the coarser sands, gravels, and cobbles. The bedrock aquifer was not included in the simulation. Inflow from the bedrock into the alluvium was added as recharge along the contact along the Katy Trail.

The bottom of the model layers was estimated by contouring the contact between layers determined from individual well logs. The available data is focused on the area of interest between the quarry and well field. There is little data for the area southwest of Osage Creek.

4.1 Boundary Conditions

A constant recharge was assigned to the cells along the Katy Trail boundary to simulate the inflow of groundwater from the bedrock-alluvium contact. A value of 26 in/yr was assigned to each boundary cell. A total of about 14,200 gpd was assigned to section of the boundary representing the discharge from the contaminated plume.

The Missouri River was simulated as a constant head boundary. The elevation of the river water surface at the point where the river meets the Katy Trail at the north end of the model area was assigned a value of 449 ft and uniformly increased upstream a rate of about 0.9 ft/mile. The actual water level in the river varies from season to season and from year to year. But this water level seemed to represent an average condition. The water level in the river has a significant effect on the groundwater levels.

The southern boundary was assigned a constant head boundary condition. The boundary was placed far enough from the area of interest between the uranium contaminant plume and the well field so as not to effect the results of the study. The boundary was assigned a constant head of 453.38 ft. The boundary allows for groundwater inflow from the Darst Bottoms area up river of the study area.

4.2 Femme Osage Slough and Femme Osage Creek

Femme Osage Slough and Femme Osage Creek probably provide a source of recharge or discharge to the alluvial aquifer. However, data on the hydraulic parameters required to estimate the recharge are not available. It is possible that they act to form a hydraulic barrier to flow of contaminated groundwater from the quarry. The slough and the creek must be included to make a complete flow and transport model of the plume and the well field area. However, for the purpose of this study it assumed that there is no contribution to the groundwater from the slough or the creek. In order to determine the flow path and concentration of the uranium contaminated groundwater, chemical and hydraulic barriers to the flow had to be removed so that a release under the assumed conditions could occur. Because the slough and the creek potentially act as barriers to the movement of the contamination they must be removed so that the contamination is free to move past the slough.

Simulations including the slough and the creek, using assumed parameter values, should be run to evaluate the potential impact of seepage from the slough or the creek on the movement of the uranium contamination plume. The slough and the creek should be modeled as river boundaries to demonstrate the potential effect on the groundwater.

4.3 Recharge from Precipitation

Recharge from precipitation was assumed to be 8 inches over the model area. This is the same value used by Layne-Western (Layne-Western, 1986) in an earlier model study of the area. This is greater than the 5 inches used in a model of the Chemical Plant site but the larger value is justified since the permeability of the alluvium is probably higher than the clay in the Chemical Plant area.

4.4 Groundwater Pumping

A total groundwater pumping rate of 10.5 mgd was divided evenly among the 8 active production wells in the well field. Although less than 8 wells may be pumping at the same time, on the average the pumping is distributed evenly over all 8 wells.

4.5 Hydraulic Conductivity Distribution

Only one aquifer test was available for the alluvial aquifer south of the slough. The test completed by Layne-Western was used to estimate a transmissivity of about 352,000 gpd/ft or a hydraulic conductivity of about 470 ft/day. This hydraulic conductivity value was applied uniformly to the lower model representing the coarser materials. Layne-Western estimated a hydraulic conductivity for the fine grained material of about 19 ft/day and this value was applied uniformly to the upper layer of the model. Other aquifer test north of the slough indicate similar low values for the fine grained alluvium.

4.6 Distribution of Uranium Contamination

The uranium plume was modeled as a constant recharge at the model boundary with a fixed concentration. The average concentration along a cross section of the plume of 4,130 μ g/l (2829 pCi/l) was assigned to the recharge. This is a very conservative assumption since it is unlikely that there is an unlimited source of uranium in soil and the original source of the contamination in the quarry has been removed. But this assumption serves the purpose of this model to show the potential capture of the plume by individual wells and the relative dilution of the plume by clean water drawn from the river due to groundwater pumping. This assumption represents an extreme case and is not expected to occur.

5.0 COMPUTER SIMULATIONS

The following distribution coefficients were supplied by Argonne National Labs (ANL) to be used in the updated computer model:

Table 1. Distribution Coefficients

·				
Soil/Water Sample ID	Depth (ft)	K _a (1) (mL/g)	K _d (2) (mUg)	K.(3) (mUg)
SO-197001-01	8-10	18	10.2	8.6
IS-197002-01	8-10			
SO-197001-02	18-20	49	4	5.4
IS-197001-02	18-20			
SO-197002-02	13-15	17	88	224
IS-197002-002	13-15			
50-197003-01	3-5	13	33	26
IS-197003-0;	3-5			
50-197003-02	10-12	11	5.7	5.3
I5-197003-02-DU	10-12			
50-197004-01	14-18	183*	180*	16
IS-1970059-01	14-16			·
50-197004-02	48-50	643*	39*	1.2
IS-197004-02	48-50			·
50-197005-01	14-16	17	38	10
IS-197003-02				
LS-1970059-02	48-50	1227*		-

The Kds marked with an '*' were not used in the computation of Kds for the model. The computation of Kds was based on U^{238} sample values. An equipment blank (IS-197002-01-EB) had a U^{238} concentration of 5.4 pCi/L and the sample concentrations ranged from 1.5 to 7.6 pCi/L. The blank contamination probably accounted for the high computed Kd's for those samples.

The computer model presented in the Remedial Investigation was used to estimate the concentrations at wells MW-1018, RMW-4, and PW-8.

Three simulations were run with different Kd's. One Kd was 1.2 ml/g, the same one used in the previous Remedial Investigation model (MKES, 1997). The second value was 14 ml/g, the average of the sample values in Table 1, except for the 3 highest values (49, 88, and 224) and those excluded because blank contamination. The third Kd was 30 L/kg, the average of all the reported Kd's except for those excluded due to the blank contamination.

6.0 RESULTS

6.1 Uranium Concentrations

Figure 2 shows the simulated concentration of the uranium plume after 100 years for a Kd of 1.2 ml/g. The figure shows that the plume reaches the production well PW-8 before any of the other production wells. The plume remains narrow as the pumping in the production well draws the plume toward it.

Figure 3 shows the approximate groundwater flow path for the simulated steady state conditions. Because of numerical dispersion and aquifer dispersion, the simulated uranium plume is spread out beyond the area indicated by the flow path.

Figure 4 shows the uranium concentration at the monitoring wells MW-1018 and RMW-4 for the 100-year simulation. Figure 5 shows the same data but only for the first 20 years so that the early data is more visible. The concentration in the production well PW-8 is shown separately in Figure 6 because the low concentration in PW-8 would not be visible at the scale of Figures 4 and 5. The concentration in PW-8 at 100 years reaches approximately 5 μ g/l while the concentration in the monitoring wells are 3,400 and 2960 μ g/l.

Figure 7 shows the simulated concentration of the uranium plume after 100 years for a Kd of 14 ml/g. The plume has just begun to move across the Femme Osage Slough. Figure 8 shows the concentration in the monitoring wells. The concentrations in MW-1018 and RMW-4 after 100 years are 178 μ g/l and 10 μ g/l. The concentration at the production well is 0 μ g/l and is not shown in the Figure 8.

Figure 9 shows the simulated concentration of the uranium plume after 100 years for a Kd of 30 ml/g. Figure 10 shows the uranium concentration at the monitoring wells. The concentrations in MW-1018 and RMW-4 after 100 years are .14 and .20 μ g/l. After 1,000 years the concentrations were 2,507 and 1,312 μ g/l. The concentration at the production well was 0 μ g/l in both simulations and is not shown in the Figure 9 or Figure 10.

Table 2 summarizes concentrations and travel times for the simulation with Kd = 1.2 ml/g. Not all of the required comparisons were made because the concentrations in the monitoring wells and the production well never reached the target concentrations. Summary tables were not made for the simulations with Kds of 14 ml/g and 30 ml/g because the target concentrations of 300 pCi/l were never reached in any of the monitoring wells and the production well never reached 14 pCi/l.

Table 2. Travel time estimates for Kd = 1.2 ml/g

Description	MW-1018	RHW-4	PW-8
Time to reach 441 µg/l (300)	129 years	26.0 years	no value
441 :1g/l in MW1018	441 µg/l (300)	32 µg/l (22)	0 µத/(
441 ;1g/l in RMW-4	1740 µg/l (1183)	441 µg/l (300)	० µदु/६
Time from MW-1018 at 441 ug/l to RMW-4 at 441 µg/l	_	13.1 years	· _

Note: Number in parentheses is pCi/L

6.2 Sampling Frequency

The sampling frequency for the monitoring wells MW-1018 and RMW-4 depend on the objective of the sampling. Assuming that the objective of the sampling is to detect the contamination before it reaches the production well PW-8 the sampling frequency depends on the travel time between the monitoring well and the production well and a target value for the production well. The travel time can be estimated from Table 2 or the figures. The sampling frequency must be equal to the travel time for the target value. However, the target value is never reached at the production well in the 100 year simulation, even for the lowest Kd value of 1.2 ml/g, and the sampling frequency can not be calculated.

The length of the simulation could be extended from 100 years to 1000 years or until the target value is reached at the production well. It is not reasonable to extend the simulation out past 100 years because it is not justified by the accuracy of the model. Small errors in model and the input data such as the Kd are magnified with time.

The model results suggest that the sampling frequency should be based on other considerations. The sampling frequency may be high during the beginning of the monitoring program and adjusted as new data are collected. Initially a quarterly sampling frequency should be used to establish seasonal changes in concentrations. Once seasonal changes are understood, the sampling frequency may be reduced to an annual basis. If trends are observed in the annual data then the frequency may be adjusted again.

6.3 Additional Monitoring Wells

The modeling results were used to determine if the number and location of the monitoring wells were adequate so that the uranium plume could not pass the southern boundary of the Femme Osage Slough undetected. The monitoring wells must be spaced close enough together so that the plume does not pass between them or around them undetected.

Figure 2 shows the monitoring well locations and the limits of the plume after 100 years for a Kd of 1.2 ml/g. It is apparent from the figure that the monitoring wells would detect the plume assuming that the plume moves uniformly as simulated in the model. It may be possible for a narrow

stringer of contaminated water to pass between the wells due to some structure in the aquifer but there is no evidence of such a structure.

There are no monitoring wells southwest of the plume near the slough and if it were possible for contaminated groundwater from the quarry or some other source to make its way around west edge of the plume it would move south of the slough undetected. It is recommended that an additional monitoring well be placed near the slough in that area.

7.0 REFERENCES

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- MK-Ferguson Company and Jacobs Engineering Group, 1997, Remedial Investigation for the Quarry Residuals Operable Unit of the Weldon Spring Site, Weldon Spring, Missouri, DOE/OR/21548-587. Prepared for the U.S. Department of Energy, Oak Ridge Operations Office, St. Charles, MO.
- Morrison Knudsen Environmental Services Division, 1997, Migration of Uranium-Contaminated Groundwater in the St. Charles County Well Field, Tech, Memo. No. 3840TM-3029-01, Doc. No. 3840-Q:HG-K-05-5618-01, p. 13.
- Pickens, J.F., and G.E. Grisak, 1981, "Scale-Dependent Dispersion in a Stratified Granular Aquifer," J. Water Resources Research, Vol. 17, No. 4, pp 1191-1211.

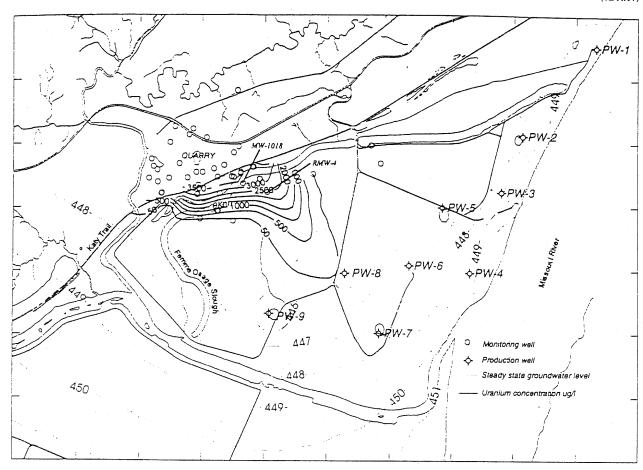


Figure 2. Contour map of simulated uranium concentration at 100 years, Kd = 1.2 ml/g

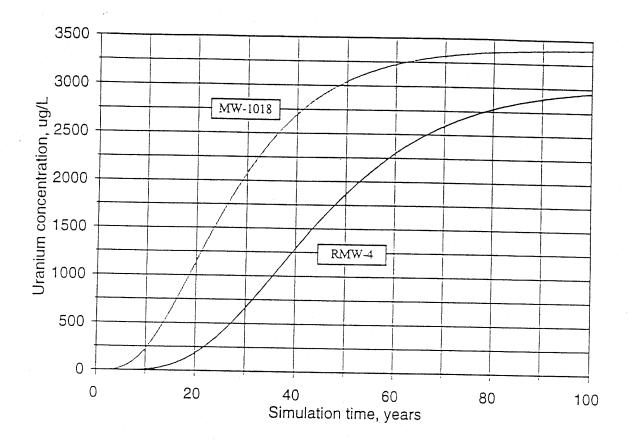


Figure 4. Simulated uranium concentration at monitoring wells MW-1018 and RMW-4, Kd=1.2 ml/g, 0-100 years.

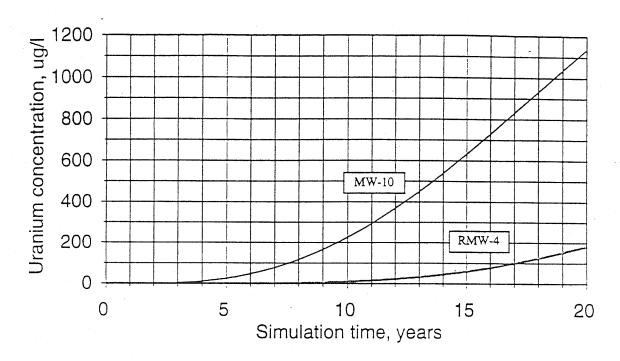


Figure 5. Simulated uranium concentration at monitoring wells MW-1018 and RMW-4, Kd=1.2 ml/g, 0-20 years.

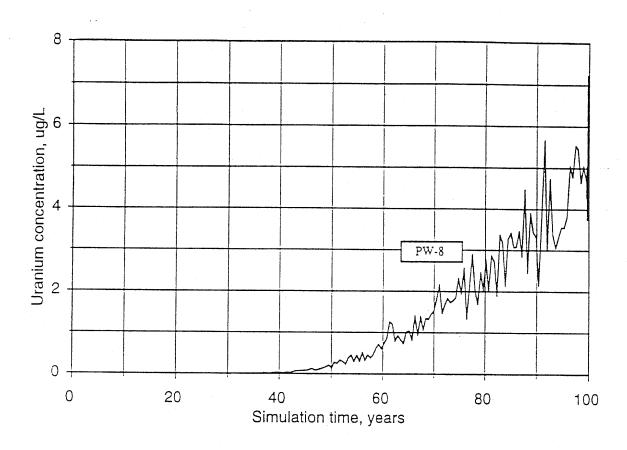


Figure 6. Simulated uranium concentration at production well PW-8, Kd=1.2 ml/g

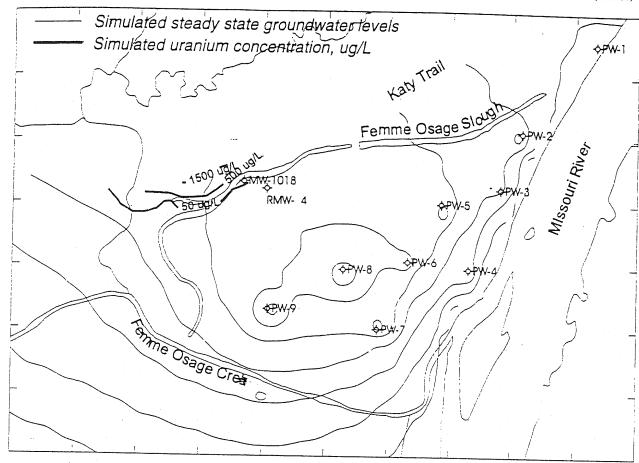


Figure 7. Contour map of simulated uranium concentrations at 100 years, Kd = 14 ml/g

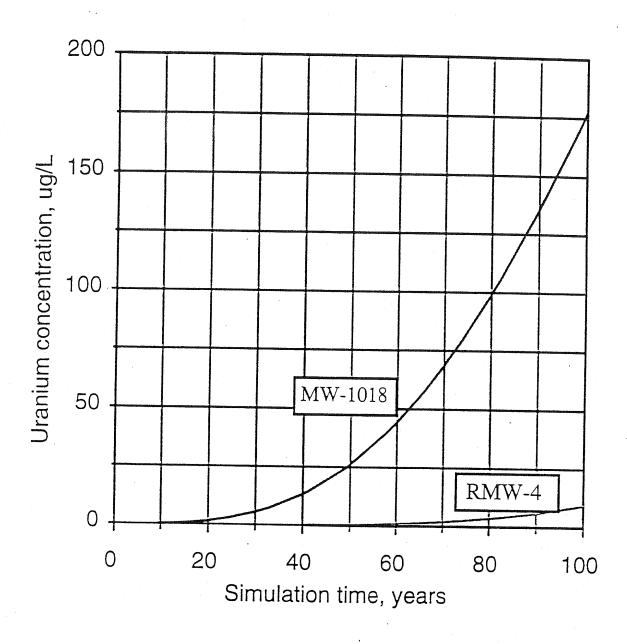


Figure 8. Simulated concentrations at monitoring wells, Kd = 14 ml/g

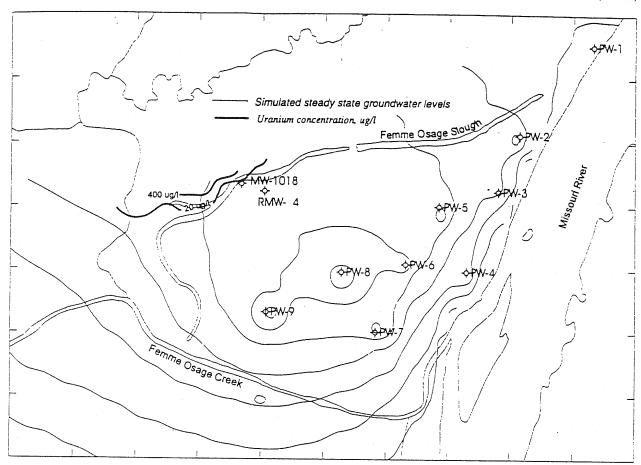


Figure 9. Contour map of simulated uranium concentrations at 100 years, Kd = 30 ml/g

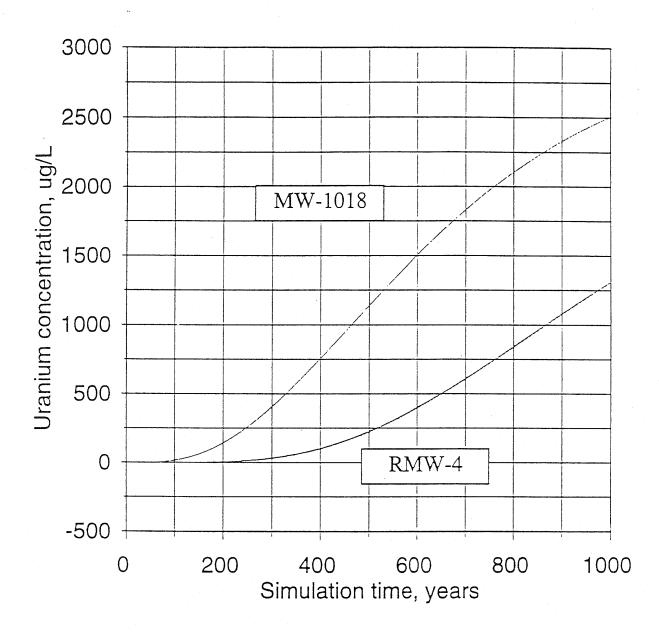


Figure 10. Simulated concentration at monitoring wells, Kd = 30 ml/g

APPENDIX B Long-Term Monitoring Evaluation

B. LONG-TERM MONITORING LOCATION EVALUATION

Monitoring locations were selected to meet the following criteria:

- 1. Monitor changes and establish trends in contaminant levels in the area of known impact.
- 2. Intercept potential migration pathways from north of the slough to south of the slough.
- 3. Provide water quality data from the productive portions of the Missouri River alluvium.

An evaluation of each of these criteria is presented in the following sections. A summary for each well with comparison to the above criteria is presented in Table B-1.

The geochemistry of the shallow aquifer will be monitored at all locations selected for this plan. The geochemistry will not be a factor for adding or deleting monitoring wells into the long-term program.

B.1 Monitor Contaminant Levels in the Area of Known Impact

The horizontal and vertical extent of groundwater contaminant at the quarry has remained nearly constant over the past 13 years of monitoring (Figure B-1). Concentrations within the area of impact have exhibited downward trends since bulk water removal. Some discrete locations have exhibited upward trends in uranium. Statistical analysis of the data for seasonality has indicated that contaminant levels do not exhibit seasonal variability.

Wells that presently exhibit elevated uranium levels or detectable concentrations of nitroaromatic compounds will be used for this monitoring program. Figure B-1 will be used to identify wells that are within the area of known uranium and nitroaromatic compound impact. Locations, which may require the installation of new wells, will also be determined from this figure.

B.2 Migration Pathways from North to South of the Slough

Lateral groundwater flow in the bedrock comprising the quarry is predominantly to the south. Flow in the Missouri River alluvial aquifer south of the quarry is generally southeast to east, due to the gradient imposed by the Missouri River. Groundwater flow is captured by the production wells of the St. Charles County well field.

Wells that are screened within the alluvial materials and the Decorah Group north of the Femme Osage Slough are situated within the migration pathway from the quarry area to south of the slough. Wells that are screened at the base of the alluvium, typically near the top of bedrock, directly south of the slough intercept groundwater originating from the area north of the slough and flow south. Vertical gradients in the bedrock south of the slough are upward; therefore, bedrock south of the slough does not require monitoring.

In the alluvial aquifer north and immediately south of the slough, groundwater gradient is downward. In the same area, the hydraulic head in the underlying bedrock units is typically higher than or equals the head in the overlying alluvium, indicating upward flow form the bedrock. These two flows likely converge in the coarse-grained base materials present south of the slough and flow laterally toward the Missouri River.

B.3 Productive Portions of the Missouri River Alluvium

The coarse-grained materials present at the base of the alluvium south of the slough constitute the productive portion of the aquifer. Hydraulic conductivity values can vary by one order of magnitude between these two types of materials, indicating that groundwater movement through the coarse-grained materials is higher than that of the upper fine-grained materials. Transmissivity values also increase in areas with a thicker sequence of coarse-grained materials.

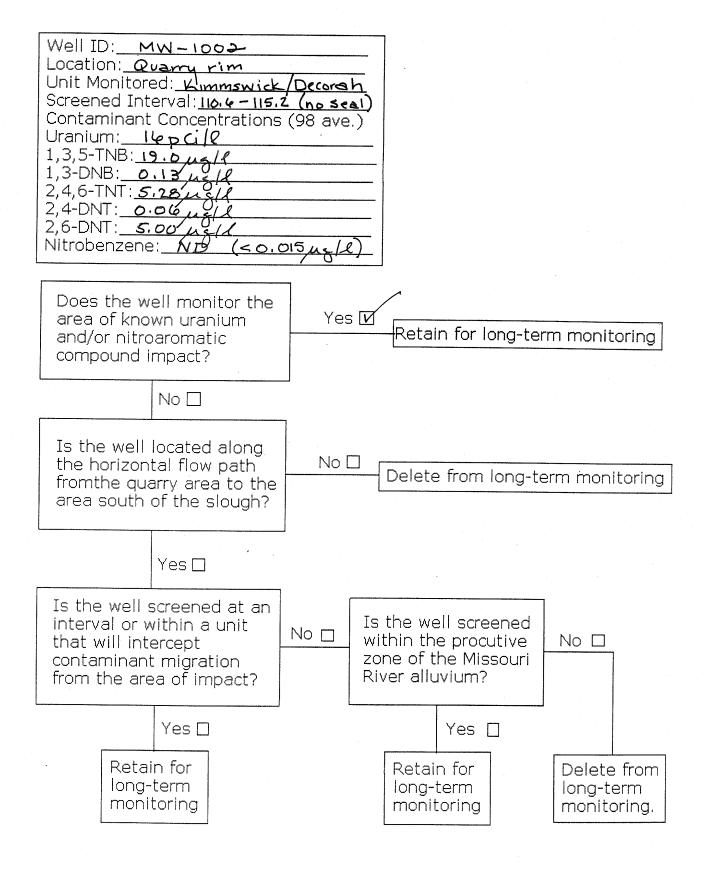
Wells that are screened in the coarse-grained materials at the base of the alluvium south of the slough monitor the productive portions of the Missouri River alluvial aquifer. This section of the alluvium also collects converging groundwater flow from the overlying fine-grained materials and the underlying bedrock.

B.4 Geochemistry of the Shallow Aquifer

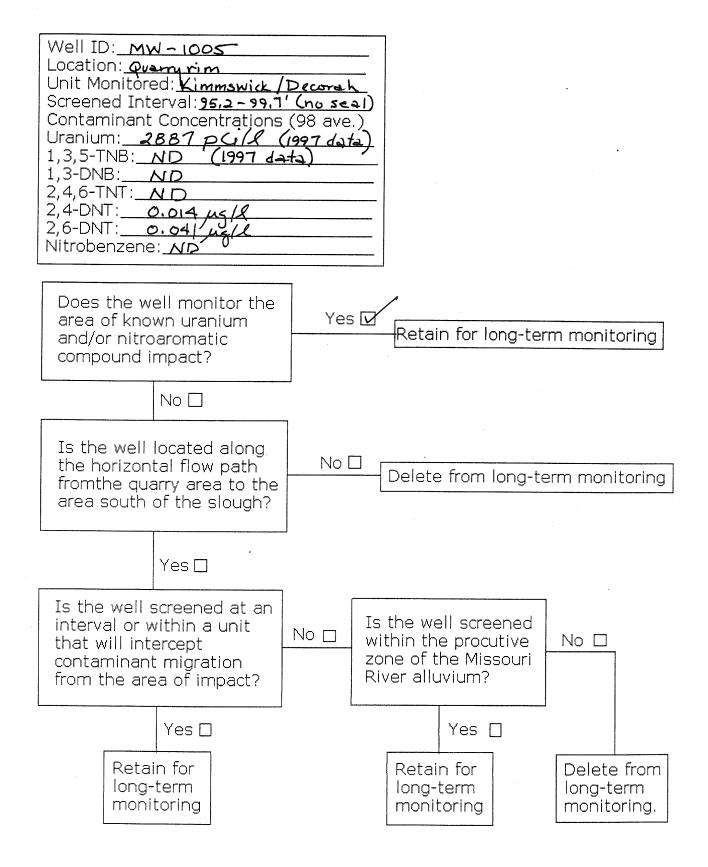
Uranium is the major quarry-related groundwater contaminant and is the only radiological constituent of the bulk waste materials that is readily dissolved in groundwater. Uranium is soluble under oxidizing conditions, but precipitates in a number of insoluble phases under reducing conditions (Ref. 4). Uranium is sorbed onto solid materials, especially iron-manganese oxides and organic matter, as observed in soil borings north of the slough (Ref. 4). In the shallow aquifer, uranium activity decreases abruptly near the northern margin of the slough, in response to the sudden decrease in the oxidation potential (Figure ____), which results in precipitation of dissolved uranium in groundwater. The sharp decrease in uranium levels indicates that sorption, which typically generates more diffuse boundaries, is not the only process attenuating the uranium in groundwater. Sorption, however, may be the primary geochemical process along the eastern and western margins of the plume, which shows a gradual decrease in uranium levels.

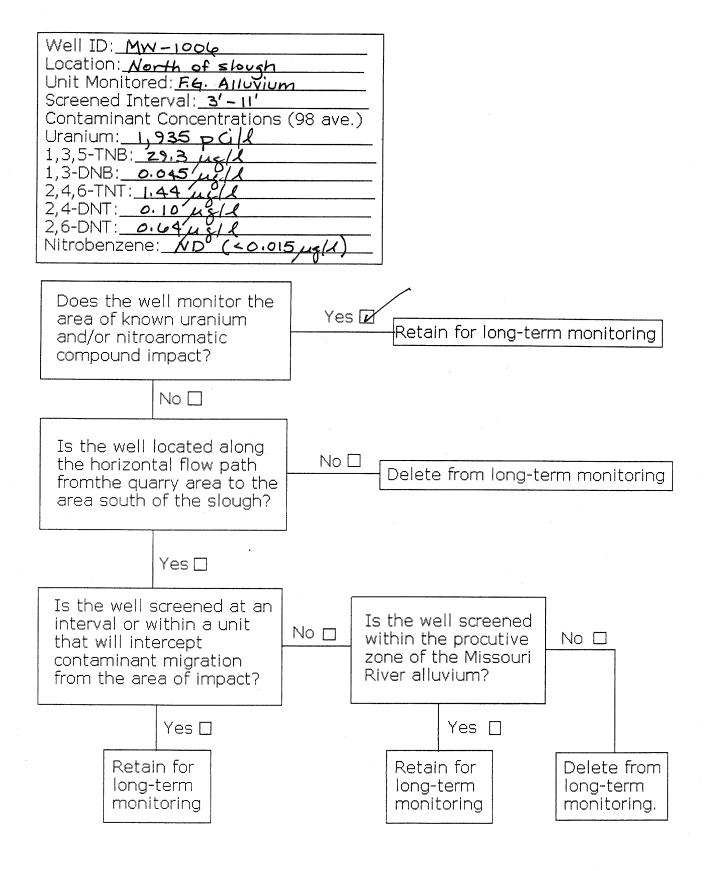
Nitroaromatic compounds, although relatively soluble water, area susceptible to various transformation processes and are likely confined to the north side of the slough primarily by a combination of biodegradation and reduction-oxidation reactions. Reducing conditions near the slough provide lower oxidation potentials to enhance the degradation of these products.

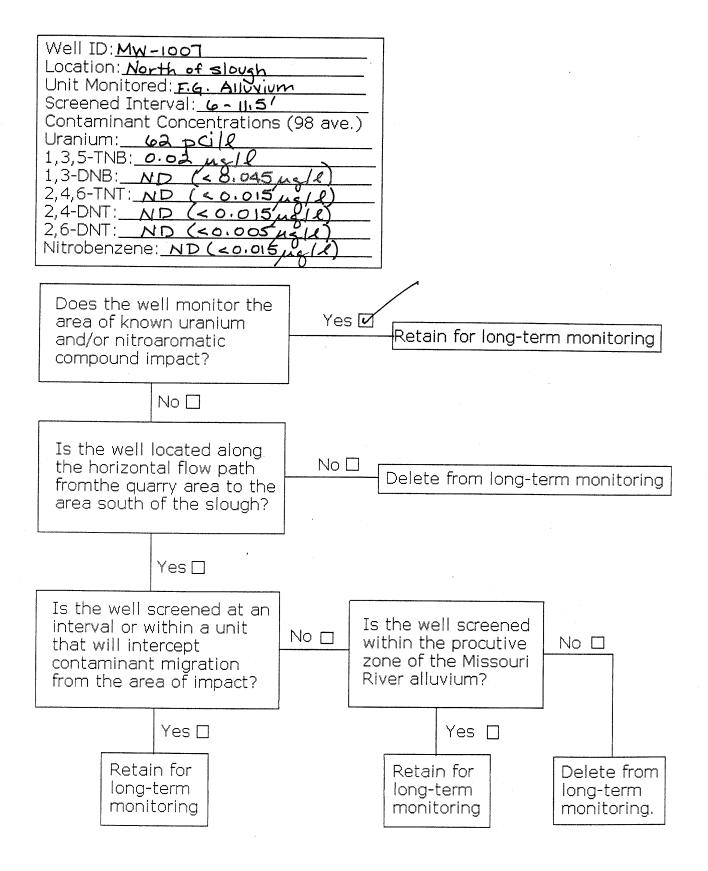
Wells within the area of known groundwater impact monitor the geochemical conditions of the aquifer that have a controlling influence on the distribution of uranium and nitroaromatic compounds into the groundwater north of the slough. Wells along the fringe of the known areas of impact and south of the slough monitor the geochemical controls on the migration of these contaminants south of the slough. These factors will not have a primary influence on the selection of monitoring locations.

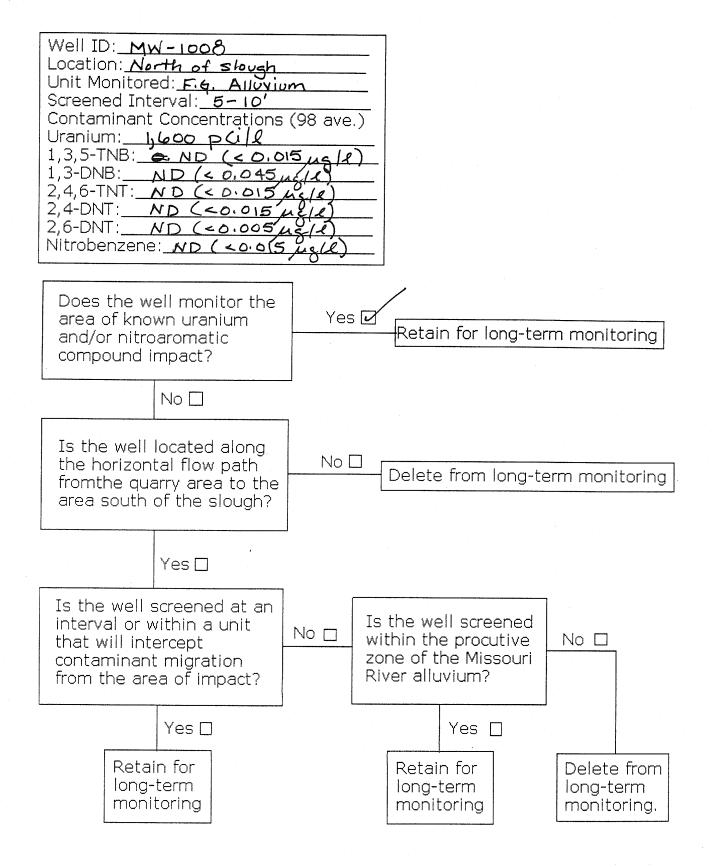


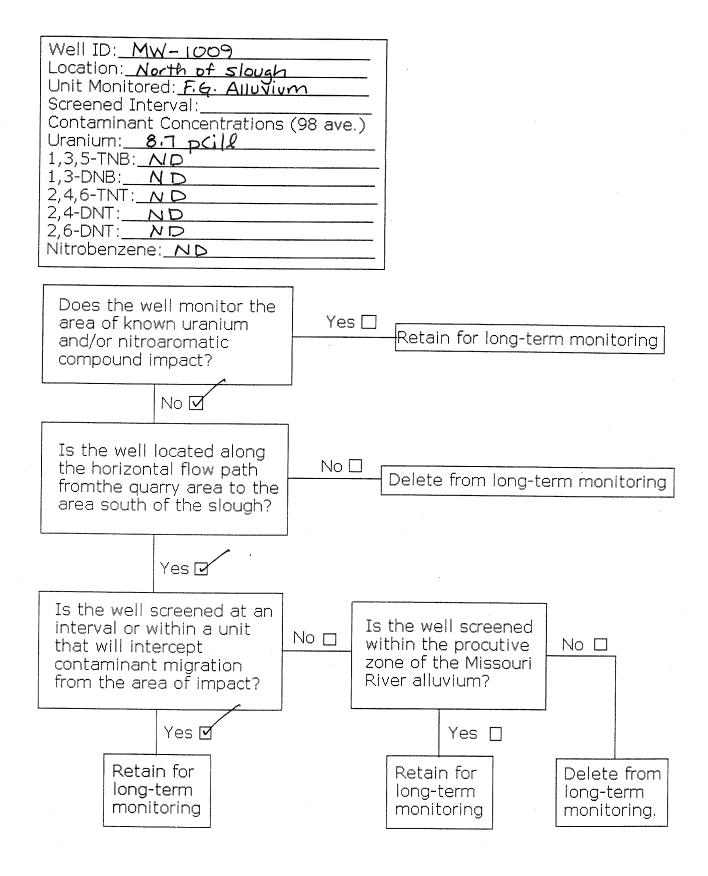
Well ID: MW -1004 Location: Quarty rim Unit Monitored: Klmmswick/ Screened Interval: 877-923 Contaminant Concentrations Uranium: 2,200 pci/l 1,3,5-TNB: 0.21 ua/l 1,3-DNB: ND (< 0.045 ua/l 2,4-DNT: 1.06 ua/l 2,6-DNT: 0.10 ua/l Nitrobenzene: ND (<0.015	(98 ave.)	86.4~ 91.0'	
Does the well monitor the area of known uranium and/or nitroaromatic compound impact?	Yes 🗹	Retain for long-ter	m monitoring
No 🗆	 		
Is the well located along the horizontal flow path fromthe quarry area to the area south of the slough?	No 🗆	Delete from long-te	erm monitoring
Yes 🗆			
Is the well screened at an interval or within a unit that will intercept contaminant migration from the area of impact?	No 🗆 wi	the well screened thin the procutive one of the Missouri ver alluvium?	No 🗆
Yes□		Yes 🗆	
Retain for long-term monitoring		Retain for long-term monitoring	Delete from long-term monitoring.

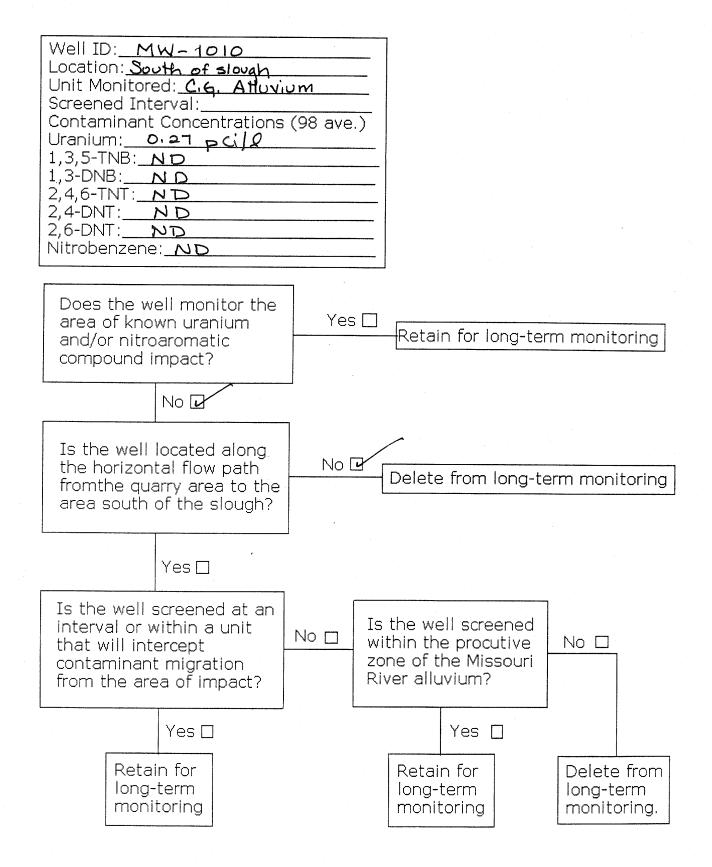


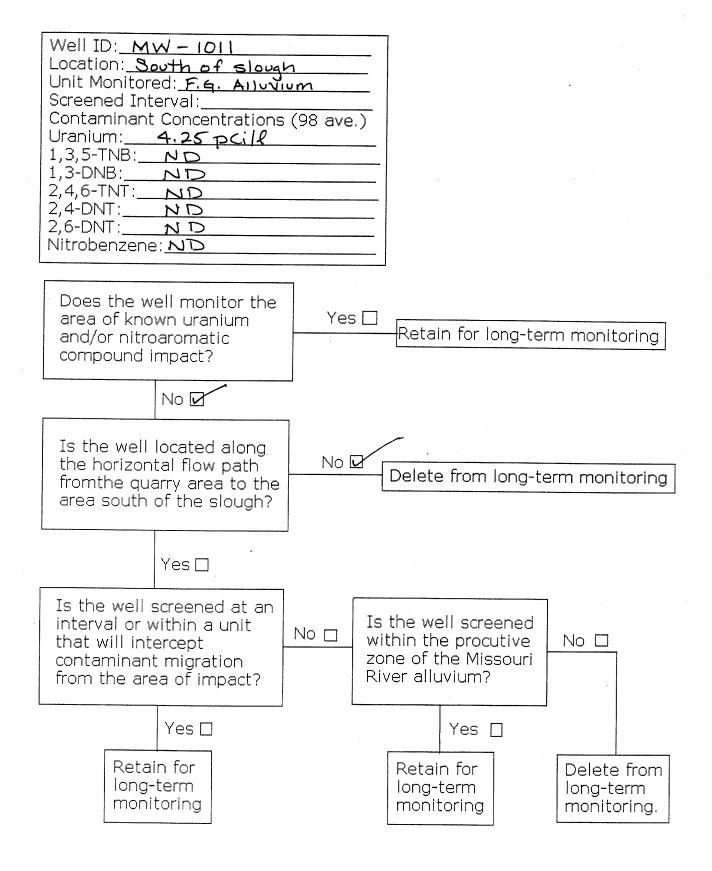




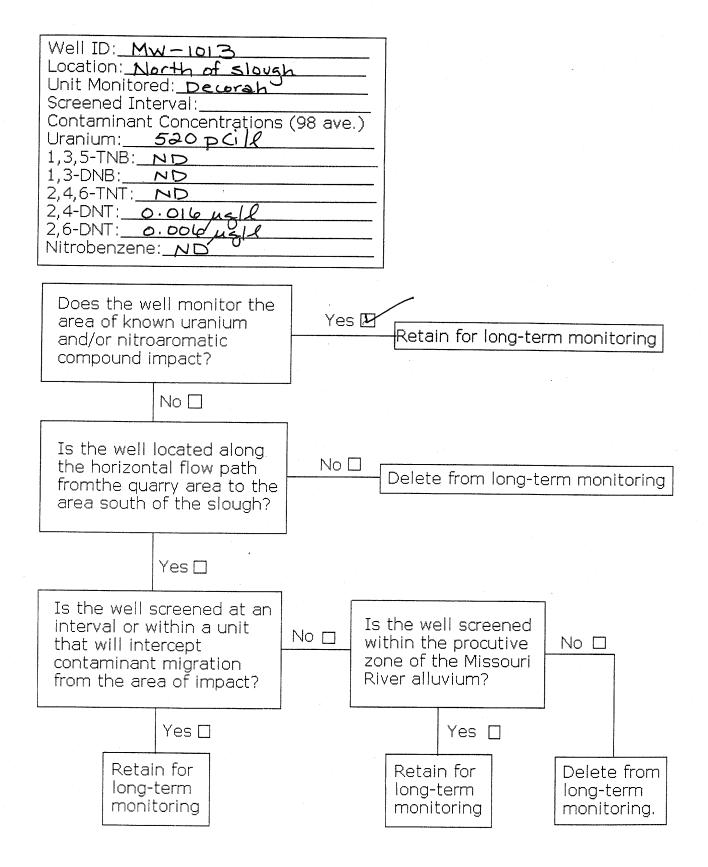






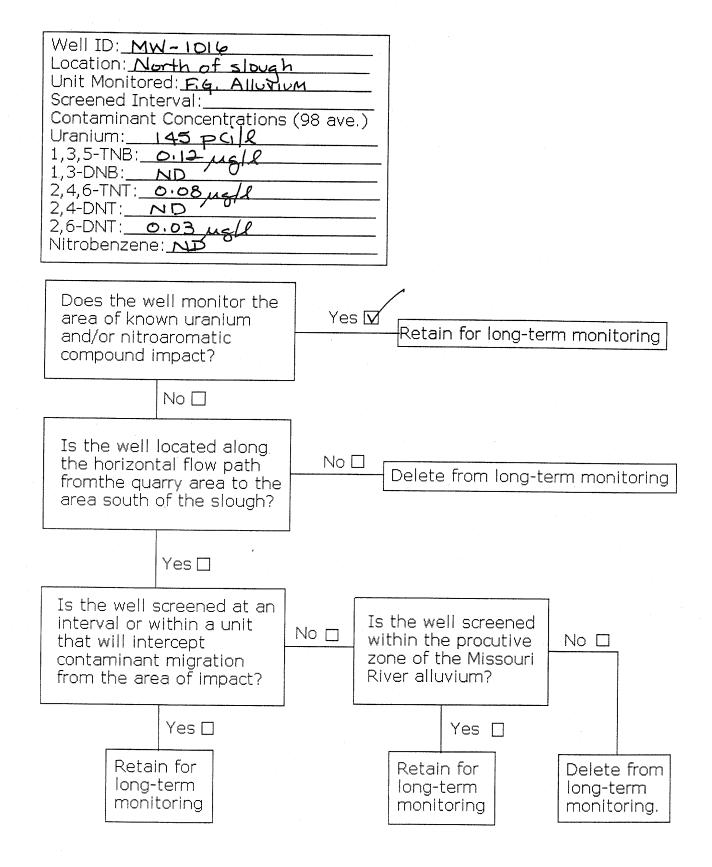


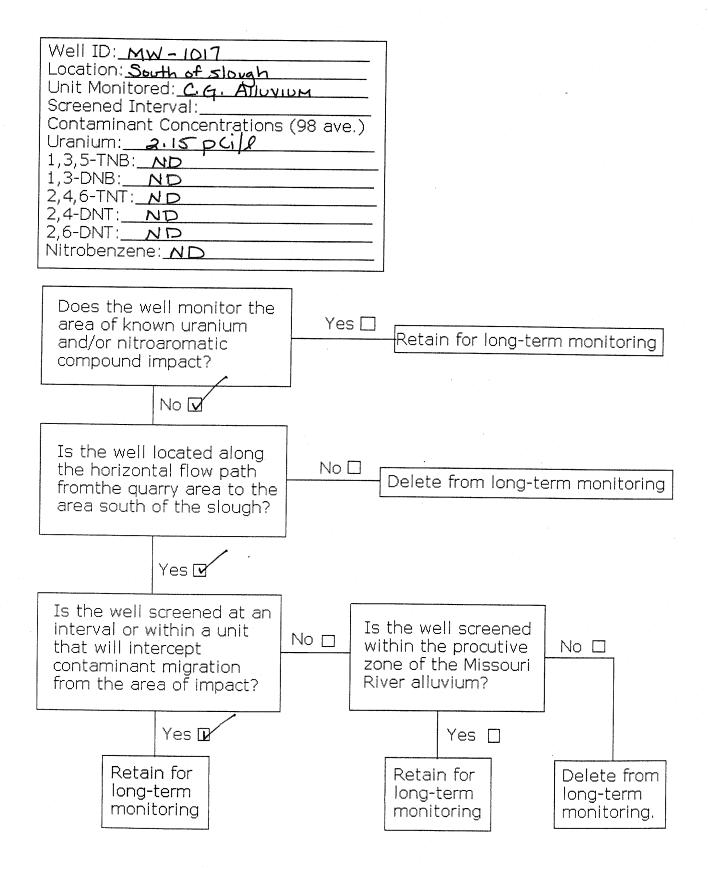
Well ID: MW - 1012 Location: North of quarry Unit Monitored: Decorah Screened Interval: Contaminant Concentrations (98 av Uranium: 2.23 pcil 1,3,5-TNB: ND 1,3-DNB: ND 2,4,6-TNT: ND 2,4-DNT: ND 2,6-DNT: ND Nitrobenzene: ND	(e.)
and/or nitroaromatic compound impact?	Retain for long-term monitoring
Is the well located along the horizontal flow path fromthe quarry area to the area south of the slough?	Delete from long-term monitoring
Yes□	
Is the well screened at an interval or within a unit that will intercept contaminant migration from the area of impact?	Is the well screened within the procutive No Dzone of the Missouri River alluvium?
Yes Retain for long-term monitoring	Yes Retain for long-term monitoring monitoring.

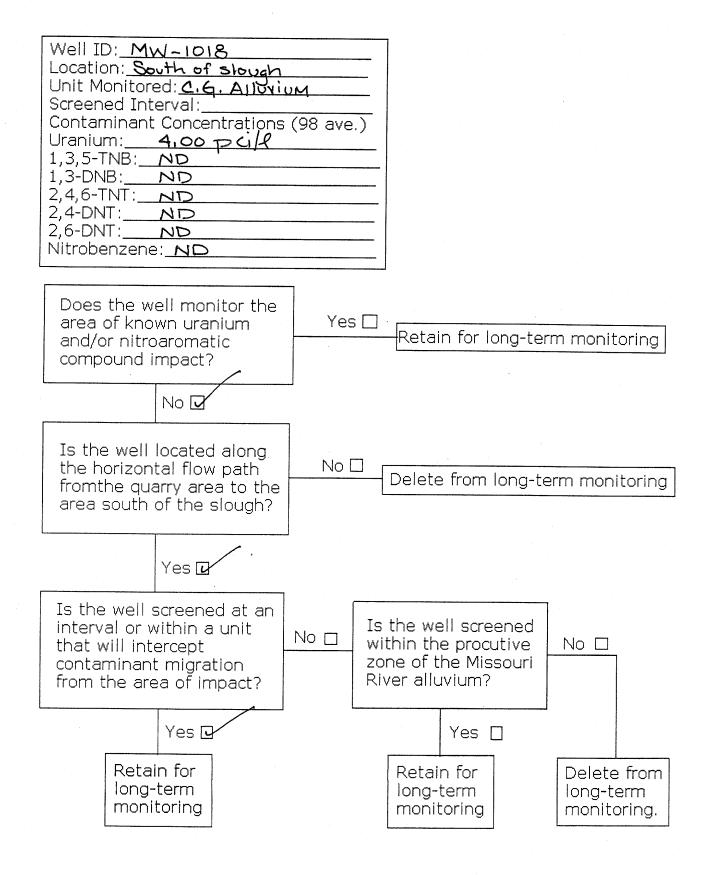


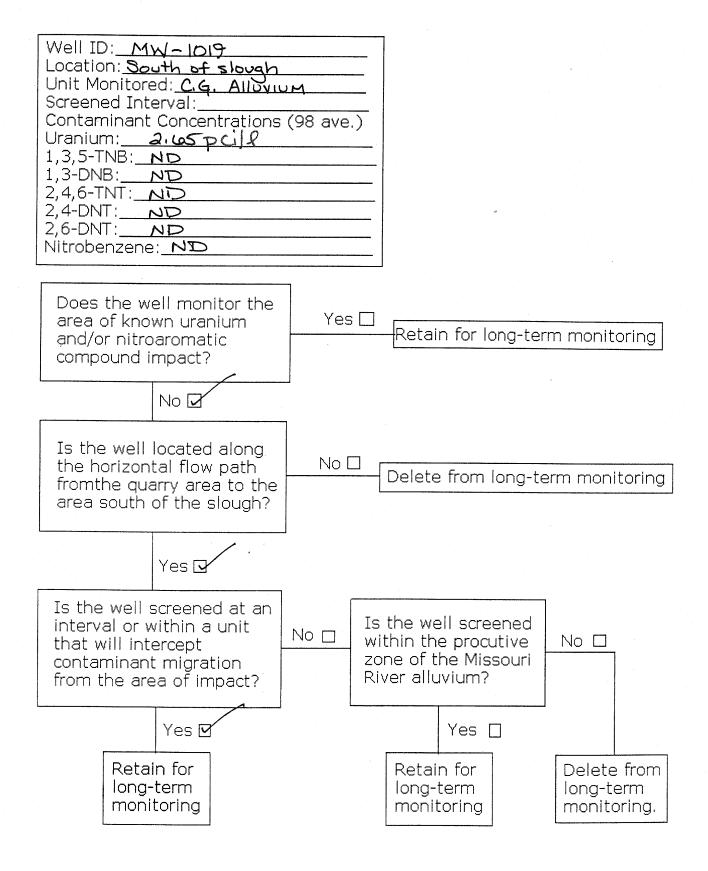
Well ID: MW-1014 Location: North of slovgh Unit Monitored: F.G. AIDVIL Screened Interval: Contaminant Concentrations Uranium: 560 pcil 1,3,5-TNB: ND 1,3-DNB: ND 2,4,6-TNT: ND 2,4-DNT: ND 2,6-DNT: ND Nitrobenzene: ND					
Does the well monitor the area of known uranium and/or nitroaromatic compound impact?	Yes ☑	Retain for Id	ong-terr	n monit	oring
No 🗆					
Is the well located along the horizontal flow path fromthe quarry area to the area south of the slough?	No 🗆	Delete from I	long-ter	rm moni	toring
Yes □					
Is the well screened at an interval or within a unit that will intercept contaminant migration from the area of impact?	NO 🗆 wi	the well screathin the procu ne of the Miss ver alluvium?	utive	No 🗆	
Yes 🗆		Yes [
Retain for long-term monitoring		Retain for long-term monitoring		Delete long-te monite	erm

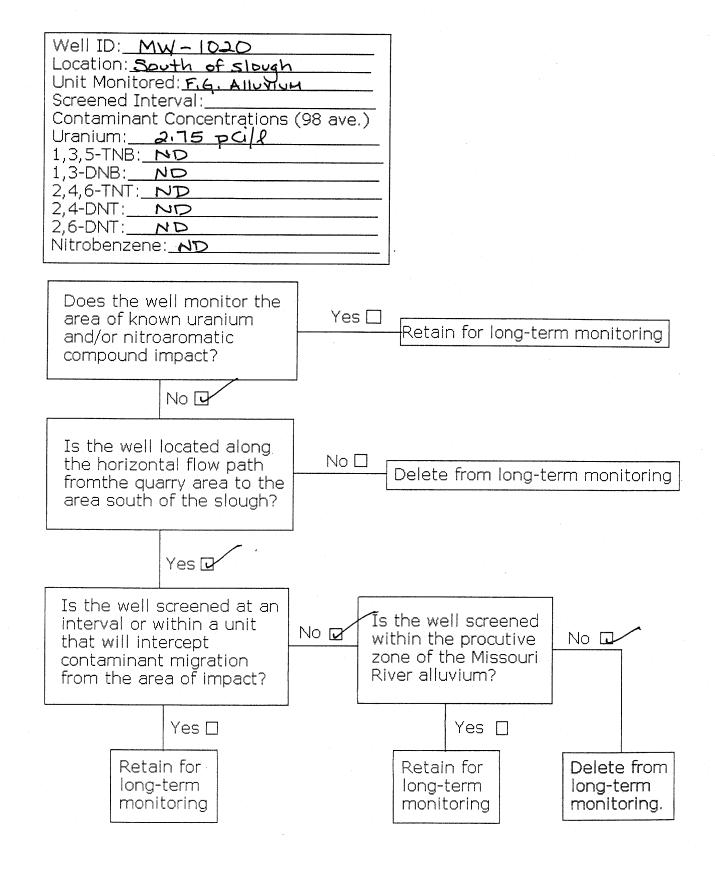
Well ID: MW-1015 Location: North of sloud! Unit Monitored: Decorate Screened Interval: Contaminant Concentrations Uranium: 216 pcill 1,3,5-TNB: 2,65 hcll 1,3-DNB: 0.10 hcll 2,4,6-TNT: 1.15 hcll 2,4-DNT: 0.03 hcll 2,6-DNT: 0.16 hcll Nitrobenzene: ND			
Does the well monitor the area of known uranium and/or nitroaromatic compound impact?	Yes ☑	Retain for lor	g-term monitoring
No 🗆			
Is the well located along the horizontal flow path fromthe quarry area to the area south of the slough?	No 🗆	Delete from lo	ng-term monitoring
Yes 🗆			
Is the well screened at an interval or within a unit that will intercept contaminant migration from the area of impact?	No 🗆 wit	the well scree thin the procut ne of the Misso ver alluvium?	ive No 🗆
Yes 🗆		Yes 🗆	
Retain for long-term monitoring		Retain for long-term monitoring	Delete from long-term monitoring.

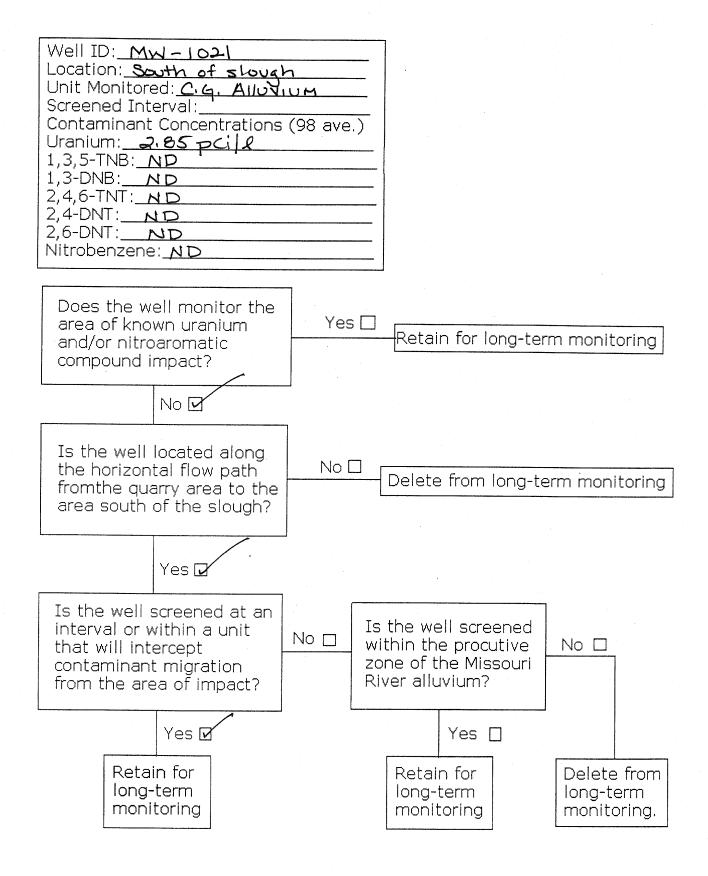


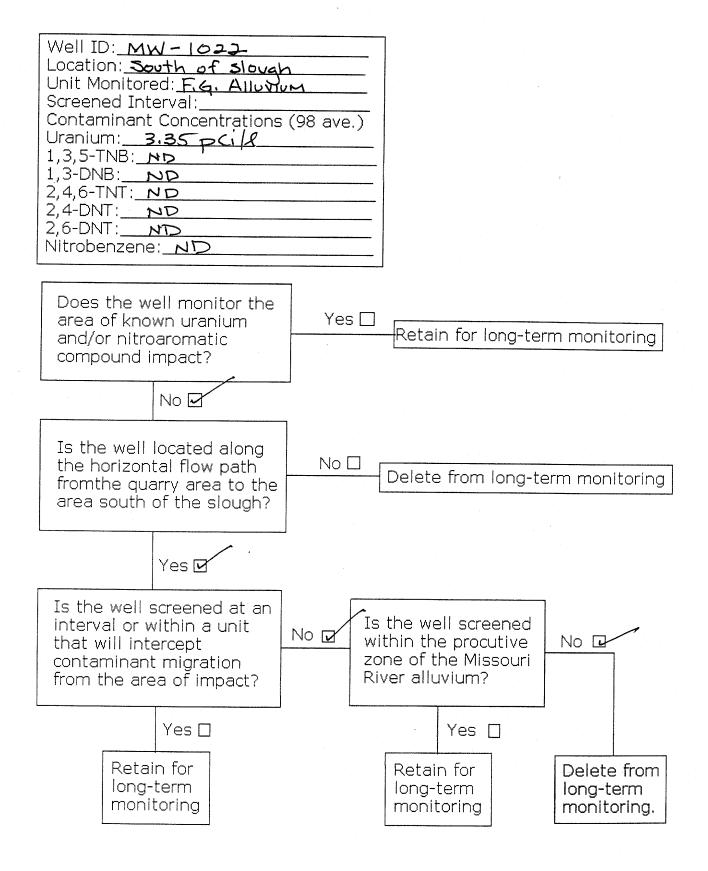


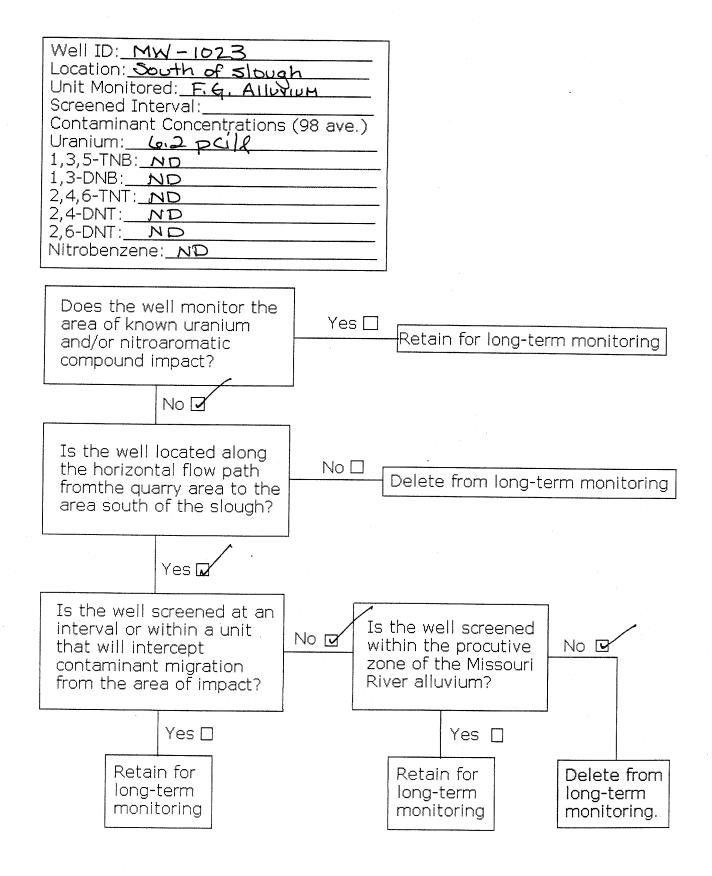


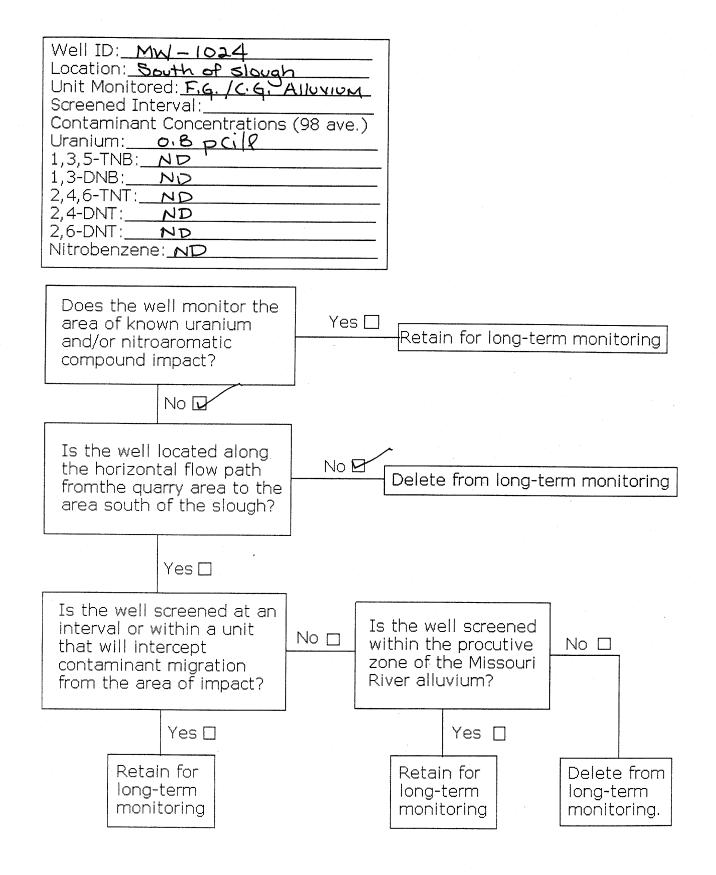




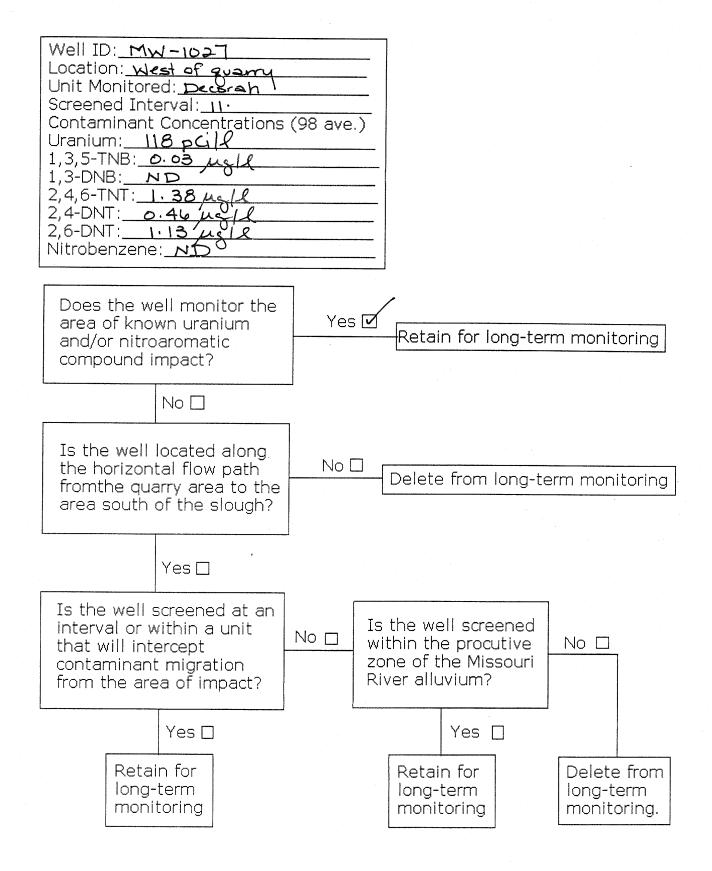






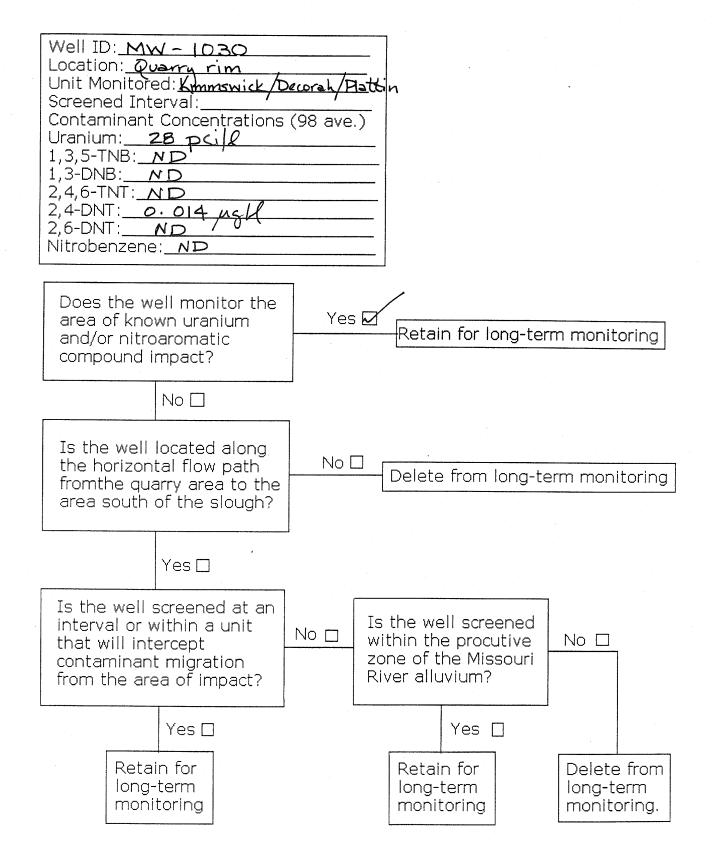


Well ID: MW - 1026 Location: Northwest of questions overburden Screened Interval: Contaminant Concentrations Uranium: 0.35 pci/l 1,3,5-TNB: ND 1,3-DNB: ND 2,4,6-TNT: ND 2,4-DNT: ND 2,6-DNT: ND Nitrobenzene: ND	Plattin		
Does the well monitor the area of known uranium and/or nitroaromatic compound impact?	Yes 🗆	Retain for long-te	rm monitoring
No 🗹	-		
Is the well located along the horizontal flow path fromthe quarry area to the area south of the slough?	No 🗹	Delete from long-te	erm monitoring
Yes □	.		
Is the well screened at an interval or within a unit that will intercept contaminant migration from the area of impact?	No 🗆 w	s the well screened ithin the procutive one of the Missouri iver alluvium?	No 🗆
Yes□		Yes 🗆	
Retain for long-term monitoring		Retain for long-term monitoring	Delete from long-term monitoring.



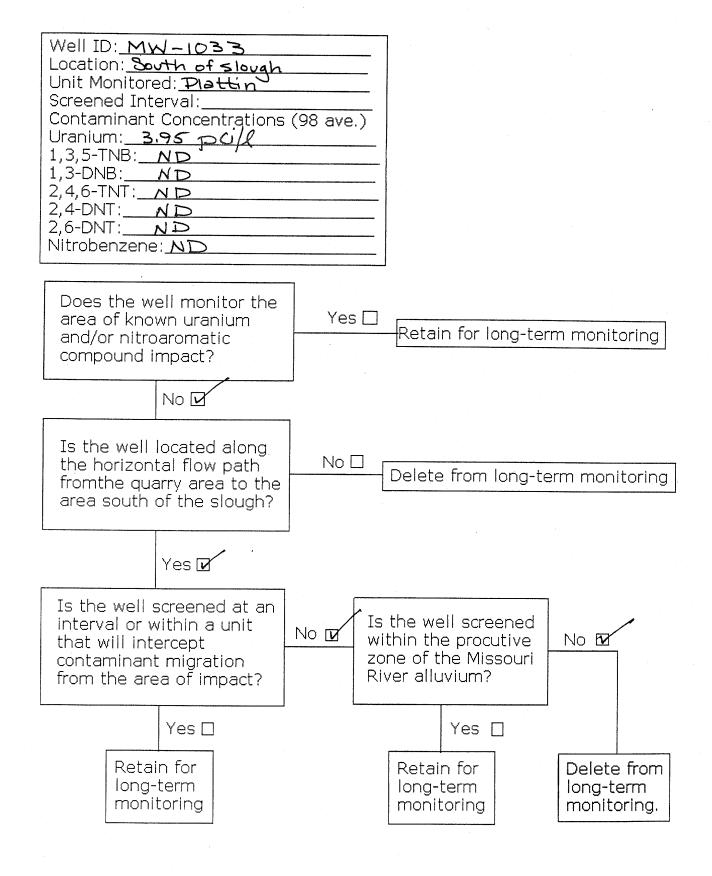
Well ID: Mw-1028 Location: North of slough Unit Monitored: Plattin Screened Interval: Contaminant Concentrations Uranium: 4.1 pci/l 1,3,5-TNB: ND 1,3-DNB: ND 2,4,6-TNT: ND 2,4-DNT: ND Nitrobenzene: ND			
Does the well monitor the area of known uranium and/or nitroaromatic compound impact?	Yes 🗆	Retain for long-ter	m monitoring
No D			
Is the well located along the horizontal flow path fromthe quarry area to the area south of the slough?	No 🔯	Delete from long-te	erm monitoring
Yes 🗆			
Is the well screened at an interval or within a unit that will intercept contaminant migration from the area of impact?	NO W	the well screened ithin the procutive one of the Missouri iver alluvium?	No 🗆
Yes 🗆		Yes 🗆	
Retain for long-term monitoring		Retain for long-term monitoring	Delete from long-term monitoring.

Well ID: MW-1029 Location: Quarry rim Unit Monitored: Kımmswick Screened Interval: Contaminant Concentrations Uranium: 3.88 pcil 1,3,5-TNB: ND 1,3-DNB: ND 2,4,6-TNT: ND 2,4-DNT: ND Nitrobenzene: ND			
Does the well monitor the area of known uranium and/or nitroaromatic compound impact?	Yes 🗆	Retain for long-te	erm monitoring
Is the well located along the horizontal flow path fromthe quarry area to the area south of the slough?	No 🗹	/ Delete from long-t	erm monitoring
Yes□			
Is the well screened at an interval or within a unit that will intercept contaminant migration from the area of impact?	NO U wi	the well screened thin the procutive one of the Missouri ver alluvium?	No 🗆
Yes□		Yes 🗆	
Retain for long-term monitoring		Retain for long-term monitoring	Delete from long-term monitoring.



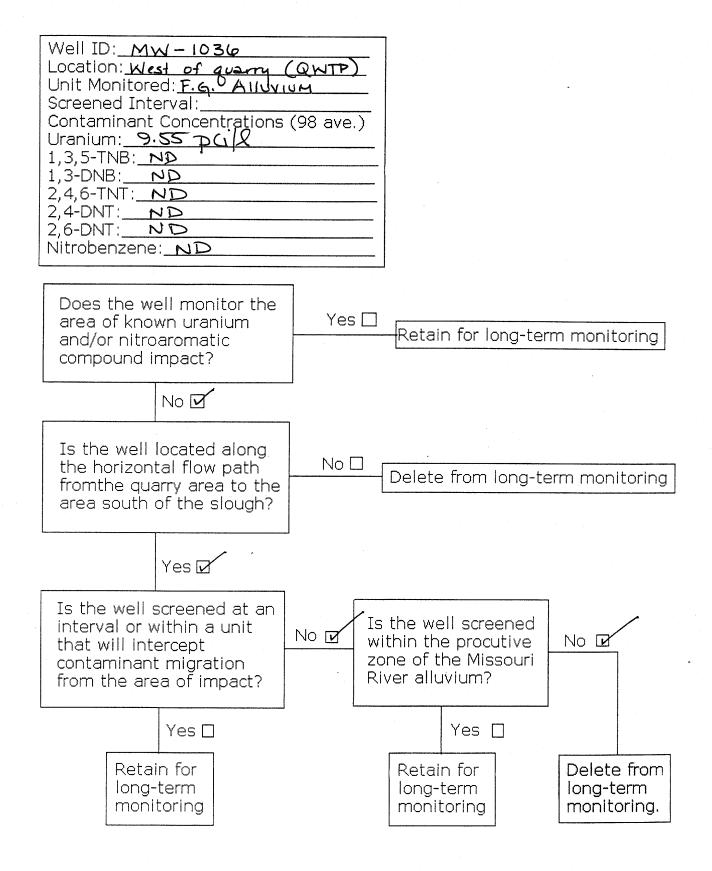
Well ID: MW-1031 Location: North of Slough Unit Monitored: Plattin Screened Interval: Contaminant Concentrations Uranium: 160 pcill 1,3,5-TNB: ND 1,3-DNB: ND 2,4,6-TNT: ND 2,4-DNT: ND 2,6-DNT: ND Nitrobenzene: ND			
Does the well monitor the area of known uranium and/or nitroaromatic compound impact?	Yes 🕡	Retain for long-ter	m monitoring
No 🗆			
Is the well located along the horizontal flow path fromthe quarry area to the area south of the slough?	No 🗆 [Delete from long-te	erm monitoring
Yes□			
Is the well screened at an interval or within a unit that will intercept contaminant migration from the area of impact?	No D wit	the well screened thin the procutive ne of the Missouri ver alluvium?	No 🗆
Yes Retain for long-term monitoring		Yes Retain for long-term monitoring	Delete from long-term monitoring.

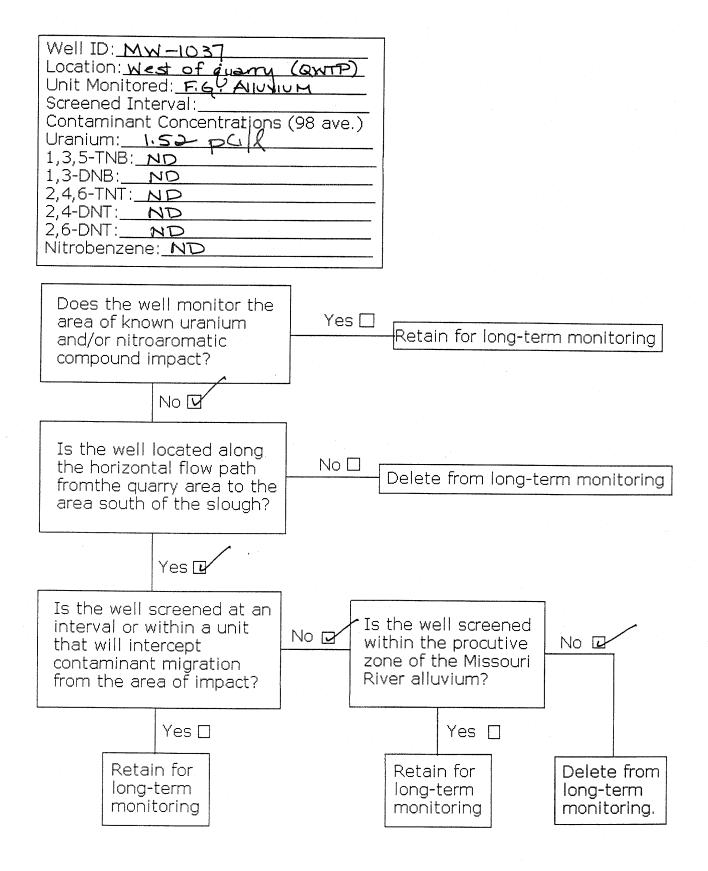
Unit Monitore Screened Inte Contaminant Uranium:	orth of slouded: Decorations concentrations 100 pcill ND ND ND ND ND ND)		
Does the we area of know and/or nitro compound in	aromatic	Yes [Retain for long-te	rm monitoring
	No 🗆			
the horizont fromthe qua	located along tal flow path arry area to the of the slough?	No 🗆	— Delete from long-t	erm monitoring
	Yes 🗆			
interval or w that will inte contaminant	ercept	No 🗆	Is the well screened within the procutive zone of the Missouri River alluvium?	No 🗆
Retai long- monit			Yes Retain for long-term monitoring	Delete from long-term monitoring.

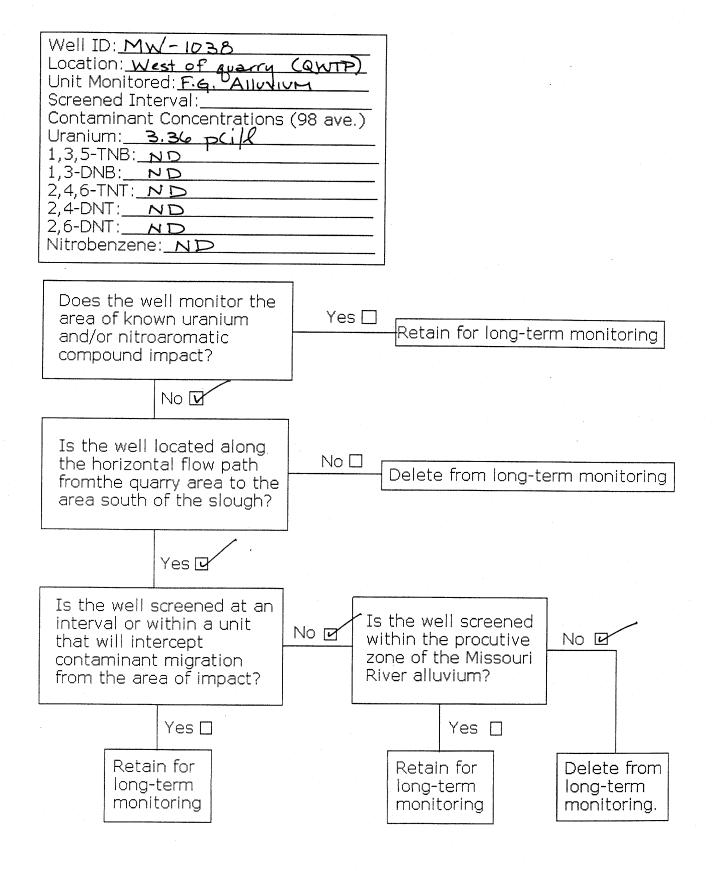


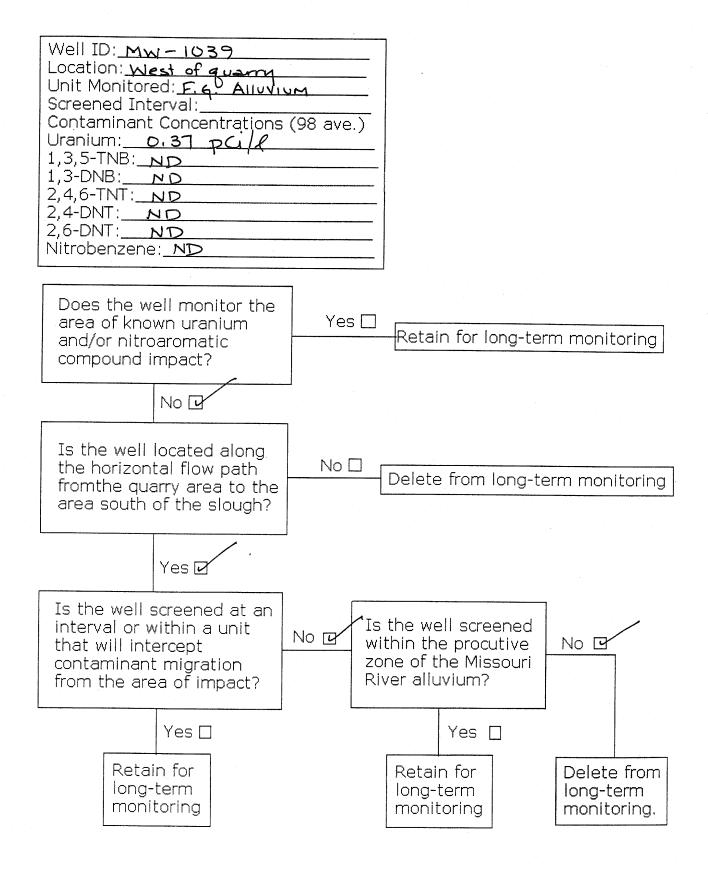
Well ID: MW - 1034 Location: North of quark Unit Monitored: Kimmswick Screened Interval: Contaminant Concentrations Uranium: 1.53 pcill 1,3,5-TNB: ND 1,3-DNB: ND 2,4,6-TNT: ND 2,4-DNT: ND Nitrobenzene: ND	JK				
Does the well monitor the area of known uranium and/or nitroaromatic compound impact?	Yes□	Retain for	long-ter	m monit	oring
No D					
Is the well located along the horizontal flow path fromthe quarry area to the area south of the slough?	No D	Delete from	ı long-te	rm mon	toring
Yes□					
Is the well screened at an interval or within a unit that will intercept contaminant migration from the area of impact?	No 🗆 wi	the well scr thin the pro ne of the Mi ver alluvium	cutive ssouri	No 🗆	
Yes□		Yes			
Retain for long-term monitoring		Retain for long-term monitoring		Delete long-te monite	erm

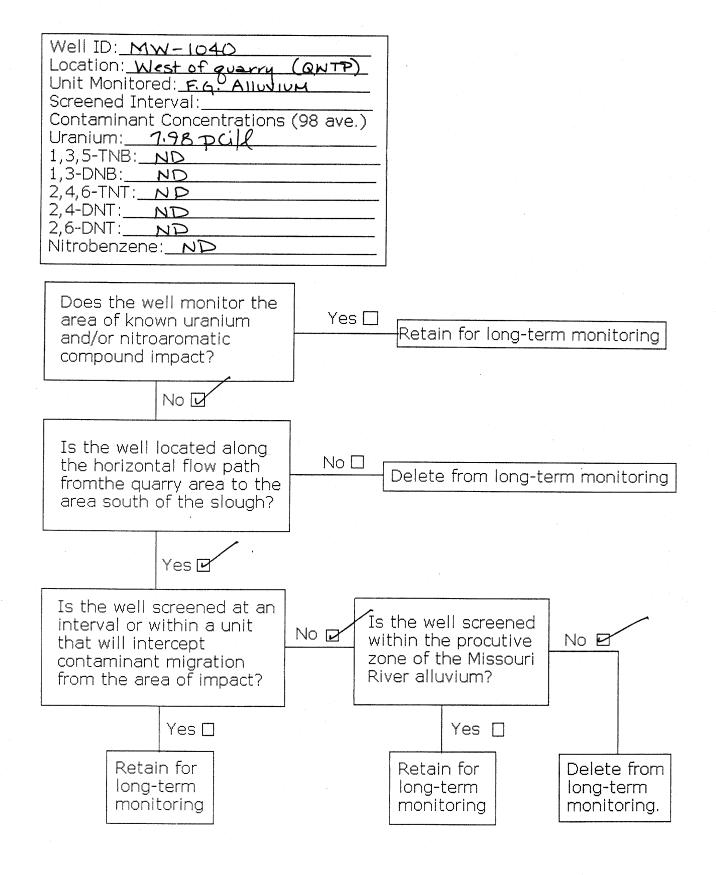
Well ID: MW-1035 Location: West of quarry Unit Monitored: F.G. Allwin Screened Interval: Contaminant Concentrations Uranium: 0.44 pCll 1,3,5-TNB: ND 1,3-DNB: ND 2,4,6-TNT: ND 2,4-DNT: ND 2,6-DNT: ND Nitrobenzene: ND	UM		
Does the well monitor the area of known uranium and/or nitroaromatic compound impact?	Yes [Retain for long-ter	m monitoring
No D			
Is the well located along the horizontal flow path fromthe quarry area to the area south of the slough?	No 🗹	Delete from long-te	erm monitoring
Yes□			
Is the well screened at an interval or within a unit that will intercept contaminant migration from the area of impact?	No 🗆	Is the well screened within the procutive zone of the Missouri River alluvium?	No 🗆
Yes Retain for long-term monitoring		Yes Retain for long-term monitoring	Delete from long-term monitoring.

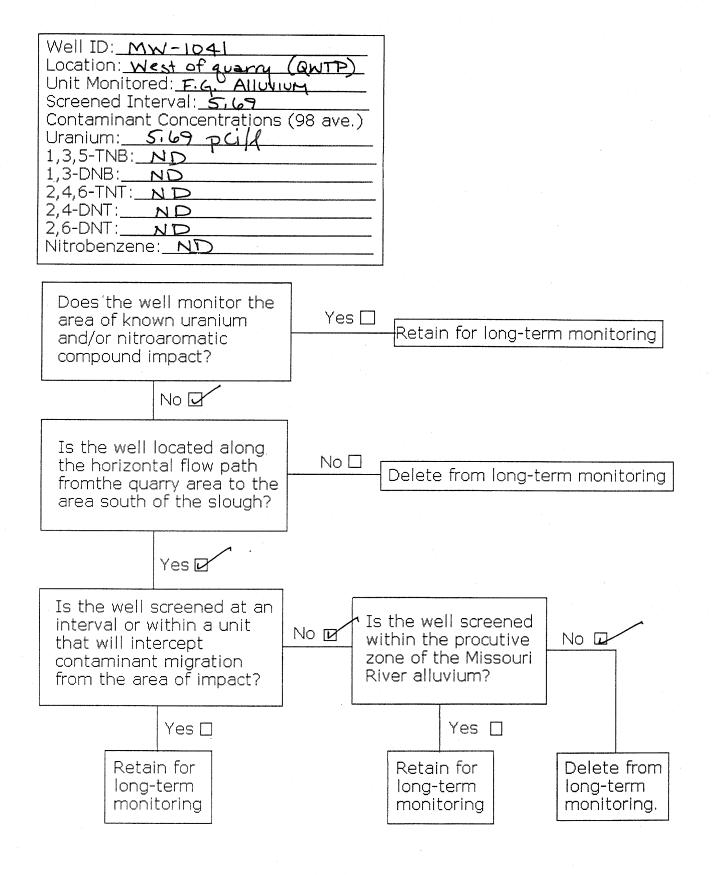


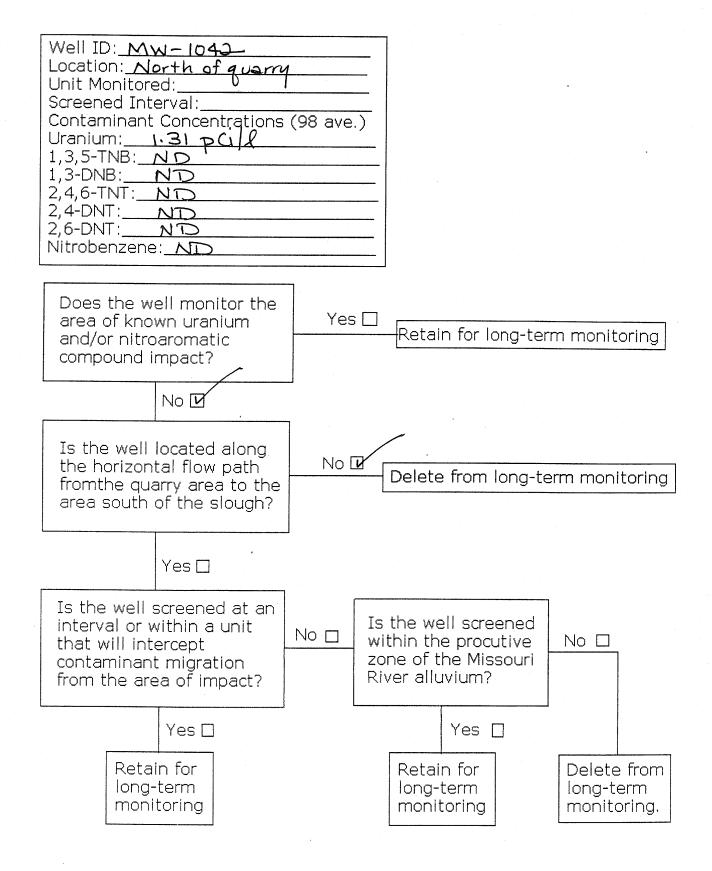


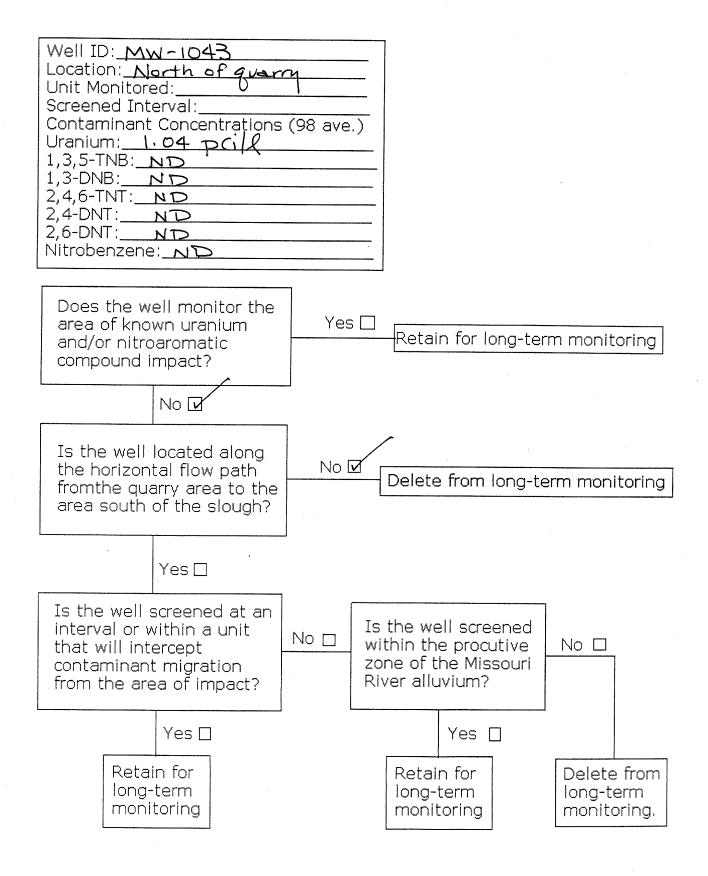


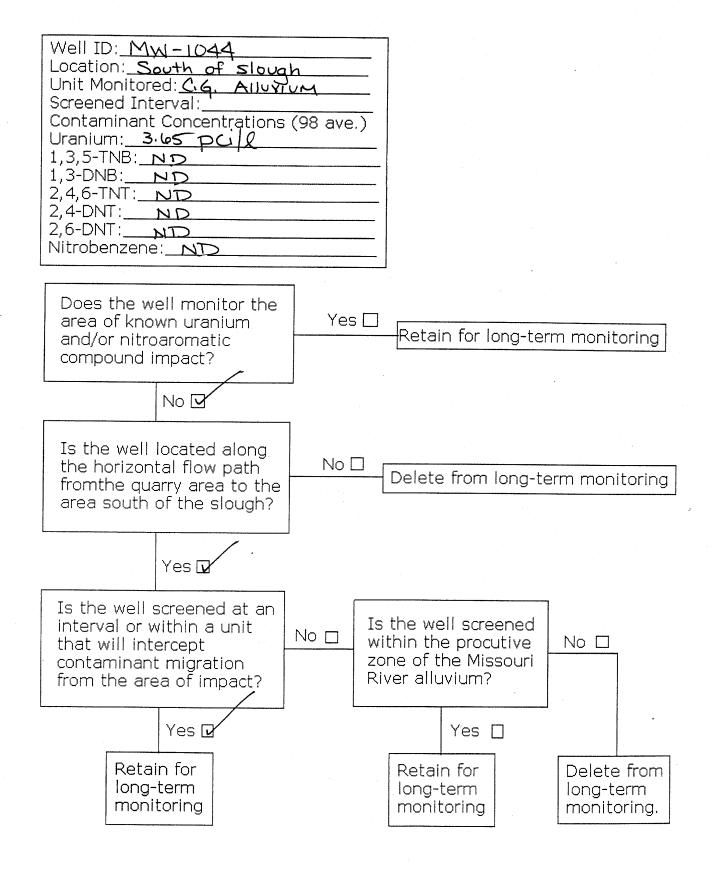






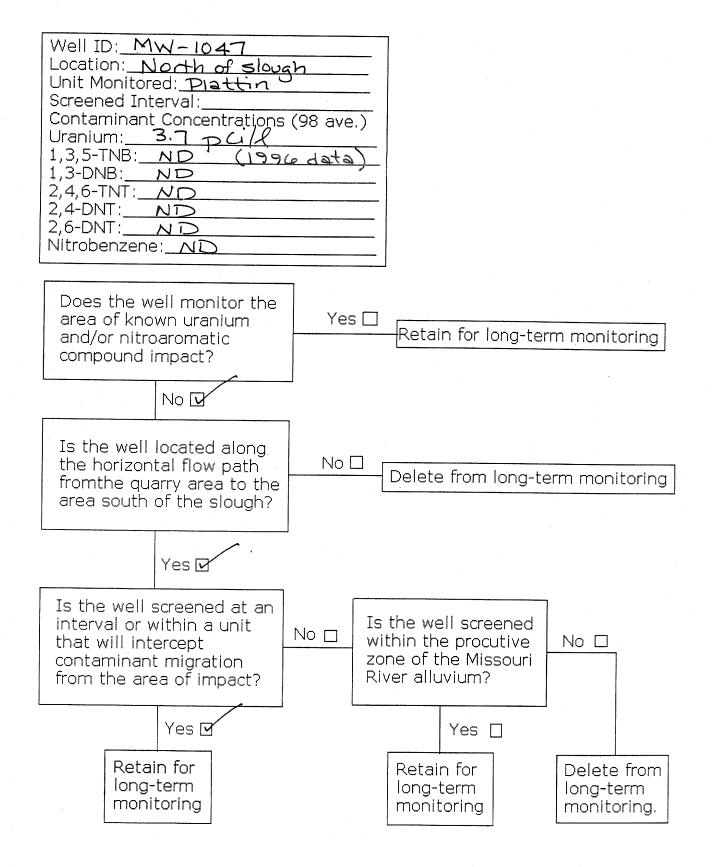






Well ID: MW-1045 Location: West of quarry Unit Monitored: F.G. Alluvium Screened Interval: Contaminant Concentrations (98 ave.) Uranium: 1,3,5-TNB: ND 1,3-DNB: ND 2,4,6-TNT: ND 2,4-DNT: ND Nitrobenzene: ND	
Does the well monitor the area of known uranium Yes and/or nitroaromatic compound impact?	Retain for long-term monitoring
Is the well located along the horizontal flow path fromthe quarry area to the area south of the slough?	Delete from long-term monitoring
Is the well screened at an interval or within a unit that will intercept contaminant migration	the well screened thin the procutive ne of the Missouri ver alluvium?
Yes Retain for long-term monitoring	Yes Retain for long-term monitoring monitoring.

Well ID: MW-1040 Location: North of Slouar Unit Monitored: Plattin Screened Interval: Contaminant Concentrations Uranium: 10.35 pc/l 1,3,5-TNB: ND (1996 c 1,3-DNB: ND 2,4,6-TNT: ND 2,4-DNT: ND 2,6-DNT: ND Nitrobenzene: ND	(98 ave.)
Does the well monitor the area of known uranium and/or nitroaromatic compound impact?	Yes Retain for long-term monitoring
No 🗆	
Is the well located along the horizontal flow path fromthe quarry area to the area south of the slough?	No Delete from long-term monitoring
Yes□	
Is the well screened at an interval or within a unit that will intercept contaminant migration from the area of impact?	No □ Is the well screened within the procutive zone of the Missouri River alluvium?
Yes Retain for long-term monitoring	Yes Retain for Delete from long-term monitoring monitoring.



Well ID: MW - 1048 Location: North of slove Unit Monitored: Plattin Screened Interval: Contaminant Concentrations Uranium: 613 PG / 8 1,3,5-TNB: ND 1,3-DNB: ND 2,4,6-TNT: ND 2,4-DNT: ND Nitrobenzene: ND	
Does the well monitor the area of known uranium and/or nitroaromatic compound impact?	Yes Retain for long-term monitoring
No 🗆	
Is the well located along the horizontal flow path fromthe quarry area to the area south of the slough?	No Delete from long-term monitoring
Yes 🗆	
Is the well screened at an interval or within a unit that will intercept contaminant migration from the area of impact?	No ☐ Is the well screened within the procutive zone of the Missouri River alluvium?
Yes□	Yes 🗆
Retain for long-term monitoring	Retain for long-term monitoring monitoring.

